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COMETARY THEORY IN FIFTEENTH-CENTURY EUROPE

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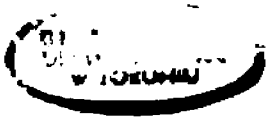

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FOREWORD

Knowledge concerning astronomy and related sciences in the fifteenth century is still very scarce. It is impossible, however, to understand the evolution of scientific methods leading to modern thought, without a thorough study of fifteenth century sources. This is especially true for optics, astronomy, as well as for arithmetic and trigonometry, as applied to astronomy e.g. by Giovanni Bianchini.

Jane L. Jervis' "Cometary Theory in Fifteenth-Century Europe" contains perfect examples of different methodological approaches of fifteenth century scholars to problems arising from the observations of the sky. Mrs Jervis shows how Jacobus Angelus (1402), still staying on the level of qualitative description of phenomena, departs from Aristotle's treatment of comets as objects of a meteorological nature, in favor of Seneca's conception considering a comet as a celestial body, namely a planet, which, owing to its eccentric orbit, can only be seen in the lower part of that orbit. Peurbach (1456) on the other hand determines quantitatively the lower part of the comet's orbit, taking for granted, according to Aristotelian cosmology, that its upper part is limited by the lunar sphere. Regiomontanus (1472) "devised a theoretical method for determining a comet's size and distance [...] but he did not apply the method". Finally, Toscanelli (1433, 1456) was interested in a purely quantitative analysis of phenomena, based on systematic observations and devoid of any cosmological speculation.

Jane L. Jervis' book continues, within "Studia Copernicana", the line of publications concerned with fifteenth-century science, namely: "Buridanism in Poland during the Pre-Copernican Period" (vol. II); "Astronomical Instruments at the University of Cracow in the Fifteenth Century" (vol. XI); "Scientific Writings and Astronomical Tables in Cracow (14th–16th c.). A Census of Manuscript Sources" (vol. XXII) and a monograph on optics (vol XXIV).

Grażyna Rosińska

INTRODUCTION

Within a cosmology based on a dichotomy between the perfect, regular, and eternal celestial realm and the imperfect, irregular, and transient terrestrial sphere, comets clearly belonged to the latter. Aristotle placed them there, and most Greek and later astronomers apparently agreed. There is no mention of comets in Ptolemy's *Almagest*, the major work of mathematical astronomy from antiquity, and throughout the middle ages observations of and commentaries on comets appear in chronicles and astrological texts where the descriptions are qualitative. Seneca held an opposing view, that comets might be celestial bodies visible to us only at the lowest points of their orbits. His views were known in the middle ages but evidently were dismissed and were certainly not the basis for systematic astronomical investigation until the fifteenth century, and even then not explicitly. It was not until late in the sixteenth century that Tycho Brahe determined that comets were beyond the moon and that the old distinctions between the celestial and terrestrial realms were no longer tenable.

I examine here one brief segment, the fifteenth century, in the history of the attempt to explain the nature and location of comets. My focus is on Europe; the Chinese chronicles were not integrated into western astronomy until much later and Islamic astronomers were as blind to comets as the European astronomers. I have selected a few treatises from the fifteenth century for careful analysis, to determine as far as possible the assumptions, stated or implied, about the nature of comets, the observational techniques employed, the character and quality of the observations, the form in which they were recorded, and the use made of these observations in the elaboration of cometary theory. In order to do this it is necessary to understand the heritage of cometary theory from antiquity and the middle ages, the context of the fifteenth century, the biographies of the people involved, and the degree of communication of cometary theories and observations – whether there was collaboration of any kind among the several practitioners I have chosen to consider.

The first treatise from the fifteenth century I examine is by Jacobus Angelus and deals with the comet of 1402. This treatise is extant in manuscript and was printed later in the century. It is notable because it contains a detailed exposition of prevailing cometary theories, the accepted

Aristotelian explanation as well as the rival and rejected theory of Seneca. It is evidence for the existence and open presentation and discussion of conflicting systems of explanation. In addition, the observational portion of this treatise, while more detailed and complete than most, is typical of the qualitative, descriptive style of most observations at that time, a style which was to continue throughout the fifteenth and well into the sixteenth century, with the notable exceptions of the more quantitative observations of Toscanelli, Peurbach, and Regiomontanus.

The second treatise I deal with is really a collection of manuscript pages by Paolo Toscanelli (1397–1482), containing observations of six comets that appeared between 1433 and 1472. The manuscript contains some brief prose passages, but is primarily a series of star charts with daily cometary positions indicated on them. There is no explicit discussion of theory. Changes in Toscanelli's observational and charting techniques are evident from one series of observations to the next. This manuscript was not published or circulated to his contemporaries at all and, as far as I have been able to determine, it remained unknown until late in the nineteenth century. There is no contemporary reference to Toscanelli's interest in comets, so it is uncertain whether his work had any influence on the development of cometary theory. He was acquainted with Regiomontanus and could possibly have spoken or written to him about his work.

A treatise on the comet of 1456 (later recognized as Halley's comet) was written by Georg Peurbach (1423–1461). It is of a style reminiscent in some respects of that of Jacobus Angelus' work but is different in that it contains what is probably the first attempt to determine a lower limit on the distance of the comet from earth by means of an estimate of the comet's daily parallax with respect to the fixed stars. The estimate was crude and gave a result consistent with the Aristotelian view that comets are located in the upper region of the atmosphere. That such an effort was made at all, however, suggests an attempt to resolve the question of the comet's location by measurement and computation, though motivation is not discussed in any of the sources I have used.

The attempt to locate comets was carried much further by Johannes Regiomontanus (1436–1476), Peurbach's student at the University of Vienna in the 1450s. In his *Sixteen Problems*, written around 1472, Regiomontanus worked out with great elegance the geometric techniques for determining the size and distance of comets by means of parallax measurements. Successful application of these techniques would have resolved the question of whether comets were atmospheric or celestial bodies, but the effect to be measured was far below the limits of naked-eye observation. Tycho Brahe used a modification of Regiomontanus' method with his observations of the comet of 1577, but concluded only that there was no detectable parallax. Regiomontanus' observation of the comet of 1472 was of a quantitative nature which would have allowed such a computation, but only one obser-

vation is extant, instead of the two required, and he never carried out the procedures he developed. The probable reasons for this are discussed in chapter VII. Regiomontanus and his disciple Bernhard Walther routinely included cometary observations among other astronomical observations, of planetary positions, eclipses, etc., and this set the pattern for the sixteenth century when comets were firmly established as celestial phenomena worthy of study by astronomers even before they were shown to be celestial bodies.

I also present a brief treatise on the comet of 1472, published many times as Regiomontanus'. I believe the attribution to Regiomontanus is wrong, but the treatise is nevertheless interesting as an intermediate stage in the transition in cometary theory under discussion, closer to Peurbach's treatise than to Regiomontanus' work in style and content.

This work concludes with a brief examination of cometary research in the sixteenth century, spurred by the apearance of several spectacular comets in the 1530s, the nova of 1572, and the comet of 1577.

I believe that two significant things have emerged from this study of cometary theory in the fifteenth century. First, a change occurred in the way comets were observed, from the isolated observations of spectacular occurrences recorded descriptively and approximately for astrological purposes, to the systematic, day-by-day observations recorded quantitatively by alignments on charts or numerically from instrumental readings, included routinely among observations of other celestial phenomena. Second, a new concern developed with determining cometary distances from earth by means of measurements of the comet's daily parallax. These efforts seem to have been directed at establishing a lower bound on cometary distance, the upper bound being understood to be the lunar sphere. Although it is nowhere explicitly stated, the underlying motive may have been to determine the upper boundary of the region of air, where it joins the region of fire. The parallax Peurbach and Regiomontanus were looking for and trying to measure was larger than 1°, the parallax of the moon, and a value of the order of 6° would have given them cometary distances consistent with Aristotelian theory. They seem to have been arguing against much larger values, which would have made comets very close to the earth indeed. The outcome of this effort to determine cometary distance by means of parallax measurement was Tycho Brahe's discovery that the comet of 1577 had no detectable parallax and was thus far beyond the moon, a result which was, I believe, quite unanticipated by the fifteenth-century researchers discussed in this study.

I am happy to acknowledge my indebtedness to the people and institutions who made this project possible. Professor Asger Aaboe of Yale, my dissertation adviser and friend, has worked closely with me, guiding, berating, and encouraging me. Professor Derek Price, also at Yale, directed my first explorations into the fifteenth century and took continuing interest in my work until his death. Professor Bernard Goldstein, now of Pittsburgh, originally sug-

gested the topic of cometary theory to me; he followed my progress at all stages, making suggestions that proved to be very helpful. The Department of History of Science and Medicine at Yale supplied me with fellowship, discussion, argument, and stimulation.

For the academic year 1976-1977 I held the Herbert E. and Mabel L. Ives Endowed Fellowship from the Educational Foundation of the American Association of University Women. The A.A.U.W. generously allowed me to accept concurrently a grant-in-aid from The Renaissance Society of America for their 1976 summer workshops in Paleography and Methods of Archive and Manuscript Research in Florence, Italy. I was honored by and grateful for both of these awards.

Finally, I wish to thank the staffs of the Beinecke Rare Book and Manuscript Library at Yale, the Archivio di Stato in Florence, and the Biblioteca Nazionale in Florence, Italy, for their cooperation and assistance. I acknowledge gratefully their permission to use and reproduce materials from their collections.

I. COMETARY THEORY IN ANTIQUITY

In antiquity there were three basic theories on the nature of comets:

1) They are an illusion only; what we call a comet is only the superposition of two normal celestial bodies whose light combines and may be distorted in some way by the atmosphere to give the appearance of a coma or a tail or both. These celestial bodies might be a planet and a star or two planets; the planets involved might be the known ones or, in some theories, unknown ones which are only visible under these special conditions.

2) Comets are real phenomena of the atmosphere, dry exhalations from the earth which are ignited under special conditions.

3) Comets are real celestial bodies of a special kind.

It was generally agreed that the appearance of a comet was a portent, though opinions varied as to the scope or sort of misfortune which was to ensue.

Our information about many of these early theories is indirect, for it is derived from later commentators, some of whom interposed their own theories. Aristotle was the earliest of these, and his influence on the succeeding two millenia can hardly be overrated. Others who were frequently cited in the middle ages and renaissance were Seneca, Pliny the Elder, and Ptolemy. In this chapter I will discuss the work of these four authorities in some detail. I also include a tentative catalog of other writers, many of whom we know only from ancient secondary sources.

ARISTOTLE

(384–322 B.C.)

Aristotle's explanation of comets remained standard for two millenia, so it is important to understand it in some detail. Book 1 of Aristotle's *Meteorology* concerns

> everything which happens naturally, but with a regularity less than that of the primary element of material things, and which takes place in the region which borders most nearly on the movements of the stars. For instance the milky way, comets, shooting stars and meteors, all phenomena that may be regarded as common to air and water, and the various kinds and parts of the earth and their characteristics. (H.D.P. Lee's translation: I, i)

Aristotle has thus clearly excluded comets from consideration as celestial phenomena, which he has previously defined as "eternal and not subject to

increase or diminution, but unaging and unalterable and unmodified" (*On the Heavens:* I, 3).

The *Meteorology* continues with a description of the first element, the celestial element, and its distinction from the four physical elements, fire, air, water, and earth, which make up the sublunar sphere. Aristotle discusses the composition of the region between the earth and the heavens, air mixed with water vapor near the surface of the earth and mixed with fire in the higher regions:

> of what we call air the part which immediately surrounds the earth is moist and hot because it is vaporous and contains exhalations from the earth, but that the part above this is hot and dry. For vapour is naturally moist and cold and exhalation hot and dry: and vapour is potentially like water, exhalation like fire. (I, 3)

The regions of the atmosphere are constantly in motion, he continues, with exhalations rising and moisture being squeezed out and falling:

> Now this primary substance and the bodies set in it as they move in a circle set on fire and dissolve by their motion that part of the lower region which is closest to them and generates heat therein. We are also led to the same view if we reason as follows: The substance beneath the motion of the heavens is a kind of matter, having potentially the qualities hot, cold, wet and dry and any others consequent upon these: but it only actually acquires and has any of these in virtue of motion or rest. (I, 3)

So matter in the upper regions of the air may be ignited by the motion of the celestial sphere and may be carried around by that motion.

Chapters 4 and 5 of Book I deal with shooting stars, and what Aristotle calls burning flames, torches, goats, chasms, and trenches, which are transient flaming phenomena. These, he says, are exhalations which have been ignited and which burn quickly, the differences in appearance being caused by differences in the shape and motion of the exhalation.

In Chapter 6 Aristotle gives the views of others about comets and shows how they all "involve impossibilities," or are contradicted by observation. Anaxagoras and Democritus believed that comets are the conjunctions of known planets. Some of the Pythagoreans, Hippocrates of Chios, and Aeschylus believed that a comet is a planet which is visible only at great intervals, the latter two saying that the tail is a reflection of the sun in the moisture attracted to the comet, only visible in certain situations. These views and the objections to them are discussed by Hellman (1944: 16–18)*. We come finally, in Chapter 7, to Aristotle's own explanation of comets:

> We consider that we have given a sufficiently rational explanation of things inaccessible to observation by our senses if we have produced a theory that is possible. [...] We have laid down that the outer part of the terrestrial world, that is, of all that lies beneath the celestial revolutions, is composed of a hot dry exhalation. This and the greater part of the air which is continuous with and below it are carried round the earth by the movement of the circular revolution: as it is carried round its movement frequently causes it to catch fire, wherever it is suitably constituted, which we maintain is the cause of scattered shooting stars. Now when as a

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* Here and in other places see References (p. 195–199).

result of the upper motion there impinges upon a suitable condensation a fiery principle which is neither so very strong as to cause a rapid and widespread conflagration, nor so feeble as to be quickly extinguished, but which is yet strong enough and widespread enough; and when besides there coincides with it an exhalation from below of suitable consistency; then a comet is produced, its exact from depending on the form taken by the exhalation. (I, 7)

This is a very coherent and powerful explanation which follows nicely, almost inexorably, from the fundamental structure of the universe set out by Aristotle at the beginning. It explains the transience of comets and their irregular motion. It also explains their effect on earth:

The fact that comets when frequent foreshadow wind and drought must be taken as an indication of their fiery constitution. For their origin is plainly due to the plentiful supply of that secretion. (I, 7)

In fact, if we accept the basic distinction between the perfect celestial realm, where motion is eternal and circular and where change and decay are impossible, and the terrestrial realm, where motion is transient and in a straight line toward the center and where all matter is continuously subject to change and decay, it is a very satisfactory explanation of the observed phenomena. To challenge Aristotle's cometary theory requires us to challenge his cosmology as well. It is essential to appreciate this fact if we are to understand the extraordinary longevity of this explanation.

The remainder of the *Meteorology* deals with the milky way, weather phenomena, rivers and oceans, winds, earthquakes, and generation and putrefaction. There is no further discussion of comets.

SENECA

(4 B.C.–65 A.D.)

Seneca was most influential as a moralist, Stoic philosopher, and literary figure. His works were known and popular throughout the middle ages, both because they were written in Latin and were thus more accessible than the works of the Greek philosophers, and because he was supposed to have been a Christian. Indeed, Clarke and Geike suggest that Seneca may well have been the chief authority from antiquity on physical science until the appearance of the twelfth-century translations of Aristotle's work through the Arabic (Clarke 1910: 1). There are more than fifty manuscripts of the *Natural Questions* extant from the twelfth to the fifteenth centuries (Corcoran 1971: I, xxvi); it was first printed in Naples in 1475 (Sarton 1927: 247).

In the *Natural Questions* Seneca expounds the views of his predecessors and contemporaries about the phenomena under discussion, expresses his own opinions, and then draws moral lessons. The study of natural phenomena is for him an important route to moral improvement. Book I treats lights or fires in the sky: rainbows, halos, meteors, and comets; comets are mentioned only briefly. Book II deals with lightning and thunder, Book III with waters on the earth, Book IV A with the Nile, IV B with hail and snow,

V with the winds, and VI with earthquakes. The seventh and last book is on comets, though internal evidence shows that this book was in fact written before Book I. Thus the subject matter of the *Natural Questions* is similar to that of Aristotle's *Meteorology* though, as we shall see, Seneca does not agree that comets are atmospheric phenomena.

Book VII opens with a general discussion about the greater attraction of the unusual than of the daily occurrence:

> If something is disturbed or flashes out beyond the customary we look at it, ask about it, point it out — — so natural it is to marvel more at the new than at the great. The same thing happens in the case of comets. If a rare fire, and one of unusual shape appears, everyone wants to know what it is and, ignoring the other celestial phenomena, asks about the newcomer, unceratin whether he ought to admire or fear it. (T. H. Corcoran's translation: VII, 1)

He wonders about the constitution of stars and planets:

> But, by Hercules, no one could study anything more magnificent or learn anything more useful than the nature of the stars and planets, whether they are of concentrated flame, which our eyes and the light itself flowing from them and the heat descending from them attests, or whether they are not flaming orbs at all but solid and sort of earthy bodies which slip through fiery tracks and take from them brightness and heat, and are not bright on their own account. (VII, 1)

Chapter 2 begins:

> It will be worth while in this investigation to inquire whether comets have the same nature as the planets and stars I spoke about above. A comet seems to have certain things in common with them: rising and setting, the same appearance, although a comet is scattered and extends farther. It is also fiery and bright. And so, if all planets are earthy bodies, comets will also have the same condition. But if comets are nothing but a pure fire which remains for six months at a time and they are not broken up by the turning and speed of the universe, then stars, too, can consist of thin matter and are not scattered by this continuous rotation of the sky. (VII, 2)

He believes that solving this question would help decide whether the earth stands still while the heavens revolve, or vice versa. This is a strikingly different approach from Aristotle's. He is asking that we study comets in order to learn more about the universe. There is no assumption here of a difference in kind between the celestial and the terrestrial realms. Seneca does not suggest that, because we are sure about the nature of the universe, then the nature of comets is absolutely determined. In Chapter 3 Seneca says:

> it is necessary to have a record of the rising of comets in times past. Because of their rarity their path cannot yet be understood, nor can it be determined whether they maintain sequences [*vices servent*] and whether a definite pattern causes them to reappear at a particular time. (VII, 3)

The study of celestial bodies is relatively recent, he says, brought into Greece from Egypt. Democritus, Eudoxos, and Conon agree that comets were not studied or understood by the Egyptians. Epigenes and Apollonius of Myndus, "who say they studied among the Chaldeans", disagree as to Chaldean, or Babylonian, cometary theory:

> Apollonius says that the Chaldeans place comets in the category of planets and have determined their orbits; Epigenes, on the contrary, says that the Chaldeans have no under-

standing of comets but that to them comets seem to be on fire from some sort of turbulence in aroused and twisted atmosphere. (VII, 4)

Seneca deals first with Epigenes. He does not tell us anything about who he was; Corcoran (1971: II, 233) and Hellman (1944: 15) cite other references to him by Pliny, Aetius, Plutarch, Fabricius, and by modern scholars, and conclude that he cannot be dated or even located with certainty, nor is it known how Seneca himself knew of him. His views on comets (or the Chaldean views described by him) have much in common with Aristotle's though they are not part of such a coherent cosmology nor are they so clearly worked out, if Seneca's rendering of them is to be relied upon. To be sure, Seneca presents them in order to refute them, which he does at great length and with some vigor (VII, 4–10).

Seneca then takes up the view that comets are produced by the conjunction of two planets or a planet with a bright star, and refutes it (VII, 12–26). He attacks a variation of this view which he attributes to Artemidorus in which innumerable planets exist which move secretly and become visible only at the extremities of their orbits, where they

mingle their light with the permanent stars and project a brighter fire than is usual in stars. This is the least of the things he lies about. His whole account of the universe is a shameless falsehood. [...] To refute these theories is like exercising by throwing arm-length punches into the wind. (VII, 13)

Artemidorus' view has some things in common with Apollonius' theory, as we shall see:

Apollonius of Myndos has a theory different from Epigenes. [note: the Latin says *in diversa opinione est*. I think Corcoran's insertion of Epigenes is mistaken; it should rather be Artemidorus.] He says that a comet is not one body composed of many planets but that many comets are planets. A comet, he says, is not an illusion or fire extending from the edges of two planets but is a celestial body on its own, like the sun and the moon. [...] On the other hand, its orbit is not clear. A comet cuts through the upper regions of the universe and then finally becomes visible when it reaches the lowest point of its orbit. [...] Comets are many and various, different in size, unlike in colour. (VII, 17)

Seneca goes on to express objections to this theory, without directly saying that they are his own objections: comets appear brightest when they are first seen, not dimmer, then brighter, then dimmer as they should if they were approaching and receding; they are not always seen within the zodiacal belt, which they would if they were planets; you can see stars through comets, "as though through a cloud", so they cannot be solid bodies (VII, 18). Nothing is known about Apollonius of Myndos except from Seneca. Later writers refer to Seneca for their statements about him, if they mention a source at all.

Seneca next talks about Zeno and "our Stoics", who believe that comets do not actually exist, but appear when stars come together and their light is seen together, or that they are formed by the ignition of condensed air, but he

disposes of these views (VII, 19–21). And finally in Chapter 22 we come to Seneca's own views:

I do not agree with our Stoics. For I do not think that a comet is just a sudden fire but that it is among the eternal works of nature. First of all, all things the atmosphere creates are short-lived, for they are produced in an unstable and changeable element. [...] Second, if fire clings to its fuel it should always descend, for the atmosphere is thicker the closer it is to the earth. A comet never descends all the way to the lowest regions of the atmosphere and does not approach the ground (VII, 22). [...] None of the ordinary fires in the sky has a curved path. It is characteristic of a planet to follow a curve.And yet did other comets do this? The two in our time did. [...] they move, preserve their continuity, and are uniform. [...] A comet has its own position and so is not quickly expelled but measures out its own space. It is not extinguished but simply departs. (VII, 23)

To the objection that if comets were planetary they should appear only in the zodiac, Seneca responds:

Who places one boundary for planets? Who confines divine things in a narrow space? Yet those very stars which you believe are the only ones that move (i.e. the planets) obviously have orbits that are different from one another. Why, then, should there not be other stars which have entered on their own route far removed from them? What reason is there that in some part or other of the sky there should not be a passageway? (VII, 24)

To the objection that the courses of comets have not been observed and their orbits charted, he says:

there are many things that we concede exist; what their qualities are we do not know. [...] Why, then, are we surprised that comets, such a rare spectacle in the universe, are not yet grasped by fixed laws and that their beginning and end are not known, when their return is at vast intervals? [...] The time will come when diligent research over very long periods will bring to light things which now lie hidden. A single lifetime, even though entirely devoted to the sky, would not be enough for the investigation of so vast a subject. [...] There will come a time when our descendants will be amazed that we did not know things that are so plain to them. [...] Some day there will be a man who will show in what regions comets have their orbit, why they travel so remote from other celestial bodies, how large they are and what sort they are. Let us be satisfied with what we have found out, and let our descendants also contribute something to the truth. (VII, 25)

Seneca's humility is indeed refreshing. He goes on to say that it is only the extended portions of comets that are transparent, through which we are able to see other stars (VII, 26). That comets have a different appearance from other celestial bodies does not mean that they are not themselves celestial; after all, the sun looks different from the moon, and still more different from the other stars.

Is not the universe, if you examine it, composed of contrasts? [...] You say that a comet is not a star because its form does not correspond to a type and it is not just like other stars. [...] Nature does not present her work in only one form but prides herself on her variety. ... Nature does not often display comets. She has assigned to them a different place, different periods, movements unlike the other celestial bodies. [...] They are not bound and confined to a narrow spot but are let loose and freely cover the region of many celestial bodies. (VII, 27)

Seneca's opinion of comets is clear and unequivocal, and remarkably openminded. It is puzzling but nevertheless true that Aristotle's explanation was not seriously challenged until early modern times.

The remainder of Book VII is of less interest for us. Seneca deals briefly with Aristotle's claim that comets portend storms, saying that they are not immediately associated but only remotely and at long range, making "the entire year suspect", another indication that comets are involved in the workings of the universe as a whole (VII, 29). There follow some pious remarks about the reverence and humility proper in contemplating the divine (VII, 30), and a tirade against the prevailing moral depravity and vice (VII, 31, 32).

PLINY THE ELDER

(23–79 A.D.)

Pliny's *Natural History* is worth mentioning, if only briefly, because it was well known and often cited in the middle ages. We have manuscripts from as early as the eighth century; it was first printed in 1469 at Venice (Rackham 1949: xii).

Pliny's discussion of comets is contained in Chapters 22 and 23 of Book II, which is the book of astronomy and of what Aristotle defined as meteorology. He begins by describing the nine different types of comets, classified according to color and shape: Pogonias (beard or mane); Acontiae (javelin); Xiphias (dagger); Ceratias (horned); Pitheus (tub); Lampadias (torch); Hippeus (horse); Argenteo (silver); and Hircus (goat). Pliny ascribes this classification to the Greeks, but does not specify his source. The nine categories are very persistent; we will see nine types of comets described in the treatise by Avogario on the comet of 1456, transcribed in Chapter 6 below, with Latin rather than Greek names, and ascribed there to Ptolemy's *Centiloquy*. In fact, as we will see, nine types are commonly ascribed to Ptolemy during the middle ages. It seems that it is the number nine that is important; the names themselves vary, and there is not a clear one-to-one correspondence between the types, some being based on shape, some on color. I have not been able to trace the origin of this tradition nor have I found any version of the *Centiloquy* which contains such a classification.

Pliny continues with a discussion of the motion of comets. Some but not all comets move; they are usually seen toward the north, chiefly in the region of the milky way. He gives several historical examples of comets and what their effects on earth were. As to their nature, he says:

> Some persons think that even comets are everlasting, and travel in a special circuit of their own, but are not visible except when the sun leaves them; there are others, however, who hold that they spring into existence out of chance moisture and fiery force, and consequently are dissolved. (H. Rackham's translation: II, 23)

He does not venture an opinion of his own. This passage suggests the views of Seneca or Apollonius of Myndos, but neither of these is mentioned in the rather long list of authorities cited by Pliny for Book II; Epigenes is. This is curious because the *Natural History* was completed in 77 A.D. (Rackham 1949: viii), some twelve years after the death of Seneca, whose

Natural Questions was apparently written between 62 and 65 A.D. (Corcoran 1971: xii). It is incredible that so omnivorous a reader as Pliny would not have been familiar with this work of a fellow Stoic. Seneca is cited as an authority for Pliny's Book IX, on aquatic animals, and for Book XXXVI, on the nature of stones.

PTOLEMY

(ca. 100–170 A.D.)

Ptolemy was the major astronomer in antiquity, eclipsing earlier writers and becoming the primary authority until early modern times. His writings include the *Almagest*, on mathematical astronomy, the *Tetrabiblos* (or *Quadripartitum*), on astrology, the *Planetary Hypotheses*, on cosmology, and the *Geography*, including map projections. In addition, the *Centiloquy*, one hundred astrological aphorisms, was wrongly ascribed to him throughout the middle ages. In cometary theory, however, he is most important for what he did not say. There is no mention whatever of comets in the *Almagest*, two brief passages in the *Tetrabiblos*, and one in the *Centiloquy*. Ptolemy thus reinforced the exclusion of comets from astronomy and confirmed their treatment as astrological and meteorological phenomena.

The *Tetrabiblos* was widely known in the middle ages and "enjoyed almost the authority of a Bible among the astrological writers of a thousand years or more" (Robbins 1948: x). The first edition, with a Latin translation, was printed at Nuremberg in 1535. There are a number of translations: one into Arabic from the ninth century, and several into Latin from the twelfth and thirteenth centuries, are the earliest ones. The first printed edition of a Latin text appeared in 1484 (Thorndike I: 110). Numerous manuscripts were in circulation.

Book I of the *Tetrabiblos* begins with a defense of astrology and goes on to describe the influences of the planets, the stars of the various constellations, and the signs of the zodiac, singly and in various configurations. Book II describes the particular influences for different climates and countries, then for different seasons. Chapter 9, Book II, discusses the colors of "eclipses, comets, and the like". This is the first mention of comets. They are important, he says,

> for these naturally produce the effects peculiar to Mars and to Mercury — wars, hot weather, disturbed conditions, and the accompaniments of these; and they show, through the parts of the zodiac in which their heads appear and through the directions which the shapes of their tails point, the regions upon which the misfortunes impend. Through the formations, as it were, of their heads they indicate the kind of the event and the [social] class upon which the misfortune will take effect; through the time which they last, the duration of the events; and through their position relative to the sun likewise their beginning; for in general their appearance in the orient betokens rapidly approaching events and in the occident those that approach more slowly. (F. E. Robbins' translation: II, 9)

Book II concludes with a discussion of the seasons of the year and the effects of the heavens on the weather:

> Of occasional phenomena in the upper atmosphere, comets generally foretell droughts or winds, and the larger the number of parts that are found in their heads and the greater their size, the more severe the winds. (II, 13)

Having discussed "the theory of universal events" (III, 1), Ptolemy goes on in Book III to the genethlialogical art, "the predictions which concern the special nature of any individual" (III, 1). He includes nativities, parents, siblings, length of life, bodily form and temperament, illness or deformity, qualities of the soul (character), and how all these are affected by celestial events prior to and at the time of birth. Book IV deals with "external accidentals" (IV, 1), or how the heavens affect the course of life, prosperity, marriage, friends and enemies, travel, cause of death, and stages of life. Comets are not mentioned in Books III or IV.

Though he does not cite Aristotle in these passages, Ptolemy clearly accepts Aristotle's location of comets in the atmosphere. He does not speculate on their constitution.

MINOR WRITERS

Numerous ancient authors are mentioned in ancient and medieval cometary treatises as having had opinions on the nature of comets. For most of them we have only secondary or tertiary references; their writings do not survive. Many of them are referred to only in passing, with very brief characterization of their cometary theories. It is useful to have a catalog of these writers with a guide to the sources, though any ordering principle turns out to be more or less arbitrary, given the scarcity of evidence. The mere number of these authors is impressive, testimony to an active interest in comets.

The most readily available modern source of information about these writers is Doris Hellman's introductory chapter in her book on the comet of 1577 (Hellman 1944: chap. 1). Her chief sources were Sarton's *Introduction to the History of Science*, Thorndike's *History of Magic and Experimental Science*, and Pauly–Wissowa's *Realenzyklopaedie der klassischen Alterthumswissenschaft*. Her discussion is organized chronologically rather than by theoretical content and the account is somewhat disjointed and difficult to follow. There is, however, a great deal of useful bibliographical information collected in one place and thus far more readily accessible than the references to cometary writers widely scattered through the volumes of Thorndike's work. The best discussion of cometary theory in antiquity that I have found is in Pauly–Wissowa (XI: 1) which relies on classical texts, as does Pingré's survey of ancient cometary theory in Volume I of his *Cométographie* (1783). The principal classical sources are Aristotle's *Meteorology*, Pliny's *Natural History*, Seneca's *Natural Questions*, Diodorus' *Bibliothecae historicae*..., and Plutarch's *De placitis philosophorum*.

For reference purposes, I have classified these minor authors according to the theory of comets to which they subscribed, in so far as this can be determined. I then list them chronologically and give the classical source and some modern references.

1) Comets are an illusion only, an optical effect in the atmosphere from the superimposed light of two normal celestial bodies in conjunction:

Aeschylus (525–456 B.C.) Aristotle, *Met.*, I, 6; Pingré I: 55.

Anaxagoras (ca. 499–428 B.C.) Aristotle, *Met.*, 1, 6; Pingré I: 51.

Democritus (ca. 420 B.C.) Aristotle, *Met.*, I, 6; Pingré I: 51.

Diogenes of Apollonia (5th c. B.C.) Plutarch III, 2; Pauly–Wissowa XI, I: 1171; Pingré I: 55; Hellman 55.

Hippocrates of Chios (ca. 450–430 B.C.) Aristotle, *Met.*, I, 6; Pingré I: 55.

Metrodorus of Chios (4th c. B.C.) Plutarch III, 2; Pingré 1: 46; Hellman 24.

Strato (ca. 288 B.C.) Plutarch III, 2; Pauly–Wissowa XI, 1: 1167; Pingré I: 46; Hellman 23.

Zeno (ca. 336–264 B.C.) Seneca VII, 19.

Artemidorus of Parion (date unknown, pre-Seneca) Seneca VII, 13; Pauly–Wissowa XI, 1: 1169; Hellman 26.

2) Comets are real phenomena of the atmosphere, terrestrial exhalations ignited under special conditions:

Xenophanes of Colophon (ca. 540 B.C.) Plutarch III, 2; Pingré I: 46.

Heraclides of Pontus (ca. 388–310 B.C.) Plutarch III, 2; Pauly–Wissowa XI, 1: 1167; Pingré 1: 46; Hellman 23.

Aristotle (384–322 B.C.) *Meteorology*; see discussion above.

Chrysippus (280–207 B.C.) Pauly-Wissowa XI, 1: 1166 cites Seneca; I cannot find the reference.

Boëthus (2nd c. B.C.) Plutarch III, 2; Pingré I: 46; Hellman 23.

Panaetius (ca. 185–109 B.C.) Seneca VII, 30; Pingré I: 43; Pauly–Wissowa XI, 1: 1166.

Asclepiodotus (lst c. B.C.) Seneca II, 26 and VI, 17; Hellman 30.

Posidonius (ca. 135–51 B.C.) Seneca VII, 20; Hellman 27–30.

Epigenes (date unknown, pre-Seneca) Seneca VII, 4; Hellman 1944: 25–26.

Marcus Manilius (lst c. A.D.) *Astronomicon libri quinque* I (an astronomical poem popular in the middle ages); Hellman 34–35.

Arrian (2nd c. A.D.) Fragments of a book on meteorology, and a monograph on comets were preserved by Stobaeus in his *Eclogarum physicarum et ethicarum libri duo*. Hellman 38–39.

Ptolemy (ca. 100–170 A.D.) *Tetrabiblos*; see discussion above.

3) Comets are real celestial bodies of a special kind:

Pythagoreans (post-Pythagoras, 6th c. B.C.) Aristotle *Met.* I, 6; Pingré I: 55.

Apollonius of Myndus (4th c. B.C.) known only from Seneca; see discussion above.

Epicurus (342–270 B.C.) Diogenes Laertes X, 111; Pauly–Wissowa XI, 1: 1171.

Olympiodorus (2nd c. B.C.) Pauly–Wissowa XI, 1: 1170 refers to Aristotle; I have not been able to find the reference.

Seneca (4 B.C.–65 A.D.) *Natural Questions* VII; see discussion above.

4) Historians who did not commit themselves to any particular theory:

Ephorus (4th c. B.C.) Seneca VII, 16.

Theophrastus (ca. 370–285 B.C.) *Concerning Weather Signs* II, 34 and 57; Seneca VII, 28.

Diodorus of Sicily (ca. 30 B.C.) in Diodorus of Sicily I, 279 and I, 449–450; Seneca VII, 28.

Plutarch (ca. 50–120 A.D.) *De placitis philosophorum* III, 2; Pingré I: 55; Hellman 24.

Pliny the Elder (23–79 A.D.) *Natural History* II, 22–23; see discussion above.

Johannes Stobaeus (5th c. A.D.) *Eclogae physicae et ethicae;* Pingré I: 56; Pauly–Wissowa XI, 1: 1165; Hellman 16.

II. THE MEDIEVAL TRADITION OF COMETARY THEORY, TO 1400

There were no new developments in cometary theory in the period before 1400. Pingré, in his *Cométographie*, vol. I, attributes this to the success of the Aristotelian and Ptolemaic systems:

> Mais le Philosophe de Rome [Seneca] avoit à peine fermé les yeux, il naquit à Alexandrie un Astronome destiné à retarder pendent seize siècles la connoissance de la vraie nature des Comètes. Claude Ptolémée fleurissoit vers le commencement du second siècle de l'Eglise: il observa beaucoup; il écrivit beaucoup: peut-être a-t-il trop peu réfléchit. Son zèle pour l'Astronomie mérite certainement nos éloges; mais c'est un problème, si ses travaux astronomiques ont plus avancé que retardé les progrès de cette science. (I: 61)

Ptolemy's work in constructing a systematic astronomy, Pingré allows, was prodigious, but

> le plein absolu, la solidité, l'impénétrabilité des Cieux qu'il faut admettre dans ce système, rend impossible le vrai mouvement des Comètes; mais il a dégradé les vérités Astronomiques, par le mélange des rêveries Astrologiques les plus absurdes. Que conclure? Ptolémée travailla beaucoup; Ptolémée ne réussit pas en tout. Que ses disciples l'eussent imité dans l'assiduité de son travail, dans l'application de ses recherches; chaque siècle auroit amené quelque nouvelle découverte: l'Astronomie se seroit perfectionnée par parties; le système de Ptolémée, convaincu d'insuffisance & de fausseté, auroit bientôt cédé la place à quelqu'autre; mais Ptolémée auroit toujours eu la gloire d'avoir frayé le premier une route, qu'il ne s'étoit pas flatté sans doute d'avoir franchie en entier. Cette conduite eût été bien simple: on ne la suivit pas. On prit tout dans Aristote & dans Ptolémée: leur zèle seul pour de nouvelles connoissances fut oublié. [...] C'est donc moins sur l'erreur des maîtres, que sur l'ineptie & la paresse des disciples, qu'il faut rejeter cette prompte décadence des Sciences, dont nous ressenton encore les tristes effets. (I: 62)

There is much Gallic hyperbole in this passage, but it is certainly true that the existence of these coherent, successful astronomical and philosophical systems helped to stifle inquiry for centuries.

Comets were not disregarded during this period. Appearances of comets were noted in the chronicles and astrological judgements were made. Theoretical discussions of comets continued to be included in works on meteorology, but there was a general consensus that comets were portentous atmospheric phenomena. There was disagreement about their location, effects, and causes: whether comets were in the upper regions of the air or in the region of fire; whether they caused wind, drought, war, pestilence, etc., or were caused by the same factors that produced these effects, i.e. excesses of exhalations from the earth; whether they were natural phenomena of the

atmosphere or special divine creations. Some still maintained that they were merely the appearance of a planetary conjunction. But there were no observations that can be considered quantitative at least until the fourteenth century. Though Seneca's views were known, they were not adopted.

Doris Hellman in her book on the comet of 1577 has collected most of the known medieval writers on comets. Her work is based largely on Lynn Thorndike's *History of Magic and Experimental Science*, volumes I–III. Sarton's *Introduction to the History of Science* also contains much valuable bibliographic information. Thorndike's *Latin Treatises on Comets* (1950) gives several important texts. Pingré, as suggested by excerpt above, passes over this period in silence, as does Delambre (1819). From these secondary sources I have compiled a catalog of cometary writers in the period to 1400, which I list first chronologically then alphabetically with brief synopses of their views and references. I shall then discuss in somewhat greater detail the work of Albertus Magnus, Peter of Limoges, and Geoffrey of Meaux, perhaps the most important figures of this period, and then briefly discuss the Arabic work on comets.

MINOR WRITERS

Origen (ca. 185–254)
Synesius of Cyrene (ca. 370–430)
John Laurentius Lydus (ca. 490–565)
Isidore of Seville (ca. 560–636)
Venerable Bede (673–735)
John of Damascus (d. ca. 750)
Albumasar (Abu Ma'shar) (786–886)
Haly ('Alī Ibn abī-l-rijāl, Albohazen, Albohali, Abenragel) (11th c.)
Haly ('Ali ibn Ridwān) (d. 1061)
Algazel (Al-Ghazzālī) (1058–1111)
Peter Abelard (1079–1142)
William of Conches (ca. 1080–1154)
Averroes (Ibn Rushd) (1126–1198)
Anonymous, Spanish (comet of 1238)
Michael Scot (d. ca. 1235)
William of Auvergne (ca. 1180–1249)
Robert Grosseteste (ca. 1175–1253)
Albertus Magnus (ca. 1193–1280)
Vincent of Beauvais (1200–1264)
Thomas Aquinas (1225–1274)
Roger Bacon (ca. 1214–1292)
Giles the Dominican (fl. 1264)
Gerard de Silteo (Feltre?) (fl. 1264)
Guido Bonatti (d. 1297)
Aegidius of Lessines (ca. 1230–1304)
Leopold of Austria (13th c.)
Henry Bate (ca. 1246–1310)
Cecco d'Ascoli (1269–1327)
Peter of Limoges (fl. 1299)
Anonymous (comet of 1301)
Anonymous (comet of 1338)
Robert of York (14th c.)
Augustine of Trent (fl. 1340)
Giovanni Villani (d. 1348)
Geoffrey of Meaux (fl. 1310–1348)
John of Legnano (d. 1383)
Conrad of Megenburg (1309–1398)
Nicholas Oresme (ca. 1323–1382)
Henry of Hesse (1325–1397)
Pierre d'Ailly (1350–1420)

Peter Abelard (1079–1142) did not believe that comets are new stars. (Thorndike II: 7; Hellman 1944: 48; Sarton II: 194–195.)

Aegidius (Giles) of Lessines (ca. 1230–1304) wrote *On the Essence, Motion, and Signification of Comets*, on the comet of 1264. In it he cites Aristotle, Seneca, Grosseteste, Albertus Magnus, John of Damascus, and Ptolemy, refuting all of them but Aristotle. He names nine types of comets but does not attribute them to Ptolemy. Sarton believes he may be the same person known as Giles the Dominican. (Sarton II: 946–947; Thorndike 1950: chap. 5 gives text.)

Albertus Magnus (ca. 1193–1280) wrote a commentary on Aristotle with numerous interpolations. He believed that comets are instruments of God's will. (Thorndike II: 517–92; Hellman 1944: 51–52; Thorndike 1950: chap. 3 gives translation; Sarton II: 934–944.) I shall discuss Albertus Magnus further below.

Albumasar (Abu Ma'shar) (786–886) was a prolific writer on astrology frequently cited as an authority who supported the atmospheric origin of comets (Hellman 1944: *passim*; Thorndike I: 649–652). He was misunderstood in the 16th century (by Maestlin, Brahe, and Cardan) as having considered comets to be celestial objects beyond Venus. (Hartner 1960: 500–505; Westman 1971: 85; Thorndike 1954: 29; Suter 1900: 28–30.)

Algazel (Al-Ghazzālī) (1058–1111) believed that comets are in the sphere of fire, above the air. His *De naturalibus* was cited by Roger Bacon and by Jacobus Angelus. (Hellman 1944: 54; Sarton I: 753–754; Suter 1900: 112.)

Anonymous Spanish writer on the comet of 1238 gives excerpts from various authorities. He supports Aristotle's theory with observations of his own and gives nine types of comets, attributing the classification to Ptolemy. The significance ot the comet is determined according to the zodiacal sign in which it appears. (Thorndike 1950: chap. 2 gives the text.)

Anonymous writer on the comet of 1301 (possibly Peter of Limoges) gives a description of its course with an explanation of its motion by planetary influence. He says he made his observation with a torquetum. (Thorndike 1950: chap. 8 gives the text.)

Anonymous writer on the comet of 1338 imitates the style of Aegidius of Lessines. He assumes that comets are exhalations from the earth. He locates the comet by triangulation with fixed stars and by drawing great circles through the poles and the comet's position. (Thorndike 1950: chap. 12 gives the text.)

Thomas Aquinas (1225–1274) wrote a commentary on Aristotle's *Meteorology*, with which he agreed. He added that comets are among the fifteen signs preceding the Lord's coming to Judgement. (Hellman 1944: 52; Sarton II: 914–921; Thorndike 1950: chap. 4, translation.)

Augustine of Trent (fl. 1340) wrote a tract on the plague in which he cites the evil influence of two comets seen in 1340. A comet in Leo is especially dangerous for young people. (Thorndike III: 227; Hellman 1944: 60; Sarton III: 648.)

Averroes (Ibn Rushd) (1126–1198) wrote a commentary on Aristotle's *Meteorology* which was printed in 1474. (Hellman 1944: 47; Sarton II: 355–361).

Roger Bacon (ca. 1214–1292) wrote *De cometis*, on the comet of 1260, which he believed was inflamed vapor in the sphere of fire. In its motion, a comet follows the planet or star which generates it. He cites the *Centiloquy* and Aristotle's *Meteorology* and Algazel's *De naturalibus* on comets, and Seneca on oceans, but not on comets. (Hellman 1944: 53; Sarton II: 952–967; Dreyer 1953: 234.)

Henry Bate (of Malines) (ca. 1246–1310), in his *Speculum divinorum et quorundam naturalium* of 1302, an encyclopaedia, discusses the comet of 1264. (Hellman 1944: 55–56; Sarton II: 994–995; Thorndike II: 926–930.)

Venerable Bede (673–735), in his *De natura rerum*, wrote that some comets move like planets while some are stationary; they always appear in the north, never in the west. They are always portents. In his *Historia ecclesiastica*, he notes the appearances of the comets of 678 and their significance. (Thorndike I: 635; Hellman 1944: 44–45; Sarton I: 510–511.)

Guido Bonatti (d. 1297) wrote an astrological work, the *Liber astronomicus*, in which he discusses the relationship between comets, wind, and drought. (Hellman 1944: 54; Sarton II: 988–989.)

Cecco d'Ascoli (1269–1327) stated that a comet could not have caused the darkness at the time of the crucifixion, because they are not high enough to cut off the sun's light. (Thorndike II: 961; Hellman 1944: 56; Sarton III: 643–645.)

Conrad of Megenburg (1309–1398) wrote the *Buch der Natur*, a free translation of a work by Thomas of Cantimpré (13th c.) which was wrongly believed to be by Albertus Magnus. He said that the comet of 1337 was in the highest region of the air. (Hellman 1944: 59; Sarton III: 817–821.)

Geoffrey of Meaux (fl. 1310–1348) believed that comets are produced by conjunctions of planets. He described the motion through the constellations of the comet of 1315 and also discussed the comet of 1337. (Thorndike III: chap. 19; Hellman 1944: 57–59; Sarton III: 659–660; Thorndike 1950: chapters 9–11 give texts.) I shall discuss Geoffrey of Meaux further below.

Gerard de Silteo (Feltre?) (fl. 1264) wrote the *Summa de astris*, on the comet of 1264. This work is largely based on Albertus Magnus, and cites Seneca's opinions on comets. (Thorndike 1950: chap. 6 gives text.)

Giles the Dominican (fl. 1264) wrote a treatise on the essence, motion, and significance of the comet of 1264. He cites Aristotle, Seneca, the *Centiloquy* and Haly's commentary on it, John of Damascus, Isidore, Albumasar, and Grosseteste. He lists nine types, attributing two to Aristotle, five to the Arabs, three to Ptolemy, and none to Seneca. He describes the tail, which pointed first toward one side of the head, then the other. (Thorndike II: 453; Hellman 1944: 52–53; Sarton II: 961.)

Haly ('Alī Ibn abi-l-rijāl, Albohazen, Albohali, Abenragel; 11th c.) wrote

an astrological treatise which was translated into Latin in the 13th century and first printed in Venice in 1485: *Praeclarissimus liber completus in judiciis astrorum.* He is supposed to have written a treatise on the significance of comets according to the signs of the zodiac, published in 1563 as an appendix to a book by Frytschius on prodigies of nature: *Tractatus Albohazenhalij de cometarum significationibus per XII signa zodiaci,* Nuremberg 1563. Suter does not mention this second work; I have not found it. (Hellman 1944: 46, 447; Sarton I: 715–716; Suter 1900: 100.)

Haly ('Ali ibn Ridwān; d. 1061) wrote a commentary on Ptolemy's *Centiloquy* and *Tetrabiblos,* which can be found in editions of the *Tetrabiblos* published in Venice in 1484, 1493, and 1519. (Hellman 1944: 47; Sarton I: 729; Suter 1900: 103–104.)

Robert Grosseteste (ca. 1175–1253) mentioned comets in two of his works, *De generatione stellarum,* and *De cometis.* He believed that comets are not new stars because nothing changes above the moon; therefore they belong to the sphere of the four elements but are closely associated with stars. He cites Ptolemy in listing nine types of comets. (Thorndike II: 446–447, 452–453; Hellman 1944: 49–50; Sarton II: 583–586.)

Henry of Hesse (Langenstein; 1325–1397) denied prediction from comets. In his *Questio de cometa,* on the comet of 1368, he accepted Aristotle's explanation of its composition and location, but denied its influence on earth. Winds and pestilence are due to the same cause as comets, that is, to an excess of exhalations. Their motion is due to the diurnal rotation though they are wholly within the sublunar world. (Thorndike III: chap. 28; Hellman 1944: 62–63; Sarton III: 1502–1510; Kren 1968: 269–281.)

Isidore of Seville (ca. 560–636) discussed comets in *De natura rerum.* He was hostile to astrology but accepted comets as harbingers of revolution, war, and pestilence. (Thorndike I: 633; Hellman 1944: 44; Sarton I: 471–472.)

John of Damascus (d. ca. 750), in his *Exposition of the Orthodox Faith,* said that comets are formed and dissolved by God as signs. As an example, he cited the star of the magi. (Thorndike IV: 83; Hellman 1944: 45–46; Sarton I: 507.)

John Laurentius Lydus (ca. 490–565) was a Byzantine Aristotelian. He gave ten types of comets, citing Ptolemy and Aristotle. (Hellman 1944: 43–44.)

John of Legnano (d. 1383) wrote an astrological interpretation of the comet of 1368. He accepted the Aristotelian explanation of comets. Their effects are natural and meteorological, he said, or astrological by signs and planets. For example, an excess of terrestrial exhalation makes men choleric, therefore inclined to war; furthermore, princes are dissolute and therefore specially inclined to be choleric; therefore the appearance of a comet is a good indication that wars between princes will follow. (Thorndike III: 595

–597; Hellman 1944: 60; Sarton III: 1796–1798; Thorndike 1950: chap. 13 gives text.)

Leopold of Austria (13th c.) was an Aristotelian astronomer and meteorologist. He described nine types of comets and said that their effect depends on which planet is ruling them. (Hellman 1944: 54–55; Sarton II: 996.)

Michael Scot (d. ca. 1235) was a translator from Arabic into Latin, especially of Aristotle's works. He was an astrologer and philosopher, and accepted divination from comets. (Thorndike II: 320; Hellman 1944: 48; Sarton II: 579–582.)

Nicholas Oresme (ca. 1323–1382) was an outspoken opponent of astrology. Comets may produce changes on earth, he believed, but the changes cannot be forecast accurately. He cites Seneca on a comet which had beneficial effects on earth. (Thorndike III: chap. 25; Hellman 1944: 61–62; Sarton III: 1486–1497; Thorndike 1954; Clagett 1964.)

Origen (ca. 185–254) believed that comets are omens, possibly of good as well as evil, as with the star of Bethlehem. (Thorndike I: 457; Sarton I: 317.)

Peter of Limoges (d. ca. 1306) wrote a judgement on the comet of 1299; he used a torquetum for his observations. (Thorndike 1950: chap. 7 gives the Latin text; Thorndike 1945: English translation.) See below for further discussion of this treatise.

Pierre d'Ailly (1350–1420) wrote a commentary on Aristotle's *Meteorology* which was an abbreviated paraphrase of that work. (Hellman 1944: 64; Thorndike IV: 102.)

Robert of York (14th c.), also known as Perscrutator, believed that comets are not stars but are earthly vapor containing water, which makes them glow (because water contains light). They portend war. He observed the comet of 1313. (Thorndike III: chap. 6; Hellman 1944: 56.)

Synesius of Cyrene (ca. 370–430) wrote a treatise entitled *In Praise of Baldness*. Its theme was that hairiness is evil, and because comets are hairy, they are fatal omens. (Thorndike I: 543.)

Giovanni Villani (d. 1348), the chronicler of Florence, observed two comets in 1337, one in 1340, and one in 1347. He believed that they foretold pestilence and great mortality; he was himself a victim of the plague. (Thorndike III: 287, 316; Hellman 1944: 59; Sarton III: 913–915.)

Vincent of Beauvais (ca. 1200–1264), an encyclopaedist, stated that comets portend pestilence, famine, and war. The comet of 1264 in particular foretold the death of Pope Urban IV. (Thorndike II: 459, 469; Hellman 1944: 49; Sarton II: 929–932.)

William of Auvergne (ca. 1180–1249) thought that comets forecast political events, but that the star of Bethlehem was not a comet. (Thorndike II: 371; Hellman 1944: 48; Sarton II: 588.)

William of Conches (ca. 1080–1154) believed that comets are specially created by God as signs. His work includes moral extracts from Seneca. (Thorndike II: 58; Sarton II: 197–198.)

ALBERTUS MAGNUS

(ca. 1193–1280)

Albert and his student Thomas Aquinas were responsible for integrating Aristotelian science into western European and especially orthodox Roman Catholic thought. He was a critical scholar and he subjected many authoritative statements to verification by experience. His most original work was on plants and animals but there is scarcely any topic in natural science which he did not treat competently. His work on comets is contained in his *Meteorology*, book I, tract 3; it is basically a commentary on Aristotle but contains a number of "digressions" on the views of others as well as clear statements of Albert's own views. It is different in style from Aquinas' commentary on Aristotle's *Meteorology*, which is a straightforward paraphrase with no new information.

Thorndike (1950: chap. 3, 4) gives English translations of the sections on comets by these two authorities and makes a comparison between them easy. In his *History of Magic and Experimental Science*, Thorndike devotes a long chapter to Albert (II: 517–592), discussing particularly his work in natural history and his views on alchemy, astrology, and magic.

In his tract on comets, Albert begins by discussing three opinions on comets which were discussed as erroneous by Aristotle: that a comet is a conjunction of planets; that it is vapor attracted to a planet and clinging to it; that it is the impression of starlight on humid air. He disproves these opinions giving Aristotle's objections and also objections based on his own experience. He then goes on, in chapter 4, to give "some false views which Aristotle did not bother to note", of Seneca, John of Damascus, and "certain moderns" (unnamed). He quotes John, that comets are formed and dissolved by divine command, and Seneca, that comets are among the permanent creations of nature. As Thorndike points out (1950: 65), the text quoted by Albert differs considerably from the text accepted today and quoted above in the discussion of Seneca, but the sense of the passage is preserved. Albert does not disprove these views but simply states that they are false. Certain unidentified "learned moderns" believe, he says, that a comet is an impression of one of the planets on the interface between the zones of air and fire, but he refutes this view with Aristotelian arguments.

Albert then goes on, in chapter 5, to "a digression giving the correct views of physicists, Avicenna, Algazel, Ptolemy, and many others, as to comets, who all agree on the same point."

> I say, then, that a comet is nothing else than coarse terrestrial vapor, whose parts lie very close together, gradually rising from the lower part of the upper region of the air to its upper

part, where it touches the concave surface of the sphere of fire and there is diffused and inflamed and so often seems long and diffuse. (Thorndike's translation)

The authorities he quotes in support of this view are Constantinus, Avicenna, Algazel, Alfraganus, Ptolemy, Haly, Abraham, Bugaforas, Albumasar, and Aristotle, most of whom were not specifically dealing with comets but rather with the configuration and nature of the elementary spheres. Albert mentions seeing the comet of 1240 which was near the north pole, far from the paths of the planets.

Chapters 6 through 8 are digressions to disprove the views of Seneca, John of Damascus, and the three opinions of which Aristotle disapproves; the arguments are very unsatisfactory: Seneca cannot be right because comets vanish without setting, therefore they must be extinguished; John cannot be right because comets appear in different shapes and colors (even Seneca says so) and God has no reason to introduce this variety; comets cannot be planets or associated with planets because they can be outside the zodiac; if they were stars seen through humid air then every star so seen would look like a comet. He then accurately states Aristotle's opinion of comets, which is his as well.

In chapter 10, Albert discusses why, if comets are not associated with the five planets, there are five kinds of comets. His classification is strictly based on the coarseness of the vapor: very coarse, very fine, medium, medium coarse, medium fine. It is a surprising system, not at all based on color and shape, as were the traditional systems. He does not seem to question that there are five kinds, nor does he cite a source.

In his final chapter Albert considers the astrological significance of comets. The reason they signify death of potentates and war is not apparent, he says, "since vapor no more rises in a land where a pauper lives than where a rich man resides, whether he be king or someone else". Comets have natural causes, he continues; they can be neither cause nor effect of political events. They take their significance only from Mars, because the other planets have different effects. He concludes that the first cause of comets is the force of Mars, "which is the cause of war and destruction of peoples; and so a comet is said to signify these, although its immediate significance is not connected with them". This is an excellent example of his characteristic mixture of credulity and scepticism.

PETER OF LIMOGES

(d. ca. 1306)

Peter of Limoges, canon of Evreux, was a physician, astronomer, and astrologer, who wrote a frequently published treatise on diseases of the eye. He may have been dean of the medical faculty at Paris (see Thorndike 1950: 196–198 for known and disputed facts of his life). He wrote a judgement on the comet of 1299; an anonymous treatise on the comet of 1301 is similar in

style and may also have been written by him. Thorndike gives the Latin texts of both of these tracts (1950: chap, 7, 8) and an English translation of the earlier one (1945: 3–6). They are notable for mentioning the torquetum for finding the comet's position, probably the earliest example of an astronomical instrument being used to observe a comet. This instrument, which gives positions of celestial bodies directly in longitude and latitude (ecliptic coordinates), had been in use in the Arabic observatory at Marāgha in the 13th century. Its invention has been ascribed to Nāsir-al-dīn in the 13th century, to Franco of Liege in the 11th century, and by Regiomontanus to Jābir-ibn-Aflah in the 12th century. Regiomontanus has been credited by Sarton (II: 1005) with introducing it into western Europe, but we have here a clear indication of earlier use. Franco de Polonia wrote what may be the earliest Latin treatise on the torquetum, in 1284 or perhaps earlier (Thorndike 1945: 6) and Jean de Murs in 1318 mentioned the torquetum with the astrolabe as important astronomical instruments (Thorndike III: 295). Richard of Wallingford listed the torquetum among other astronomical instruments (Lorch 1976: 33).

Peter observed the comet of 1299 from late January into March; it was of moderate size, with a tail rather long for its size, and dark blue in color. He saw it in the west in the evening, and at first it was in Taurus 18°, more than 30° south latitude, by the torquetum. After the feast of St. Matthew (February 24) it was in Taurus 14°, and 5° south latitude. Its motion was always greater northward than westward, although because its place of generation was in the upper air near the region of fire, Peter continues, its motion should have been eastward, for the air lags behind the celestial (daily) rotation. That it was not was due to the attraction of Mercury and Mars which were to the north and west of it. Mars' attraction was further demonstrated by the fact that the tail gradually turned until it was pointed directly at Mars. Peter concludes with the usual dire predictions, but notes that God is not bound by these; He may choose to avert these disasters if we have lived correctly.

The comet of 1301 appeared on the first of September and was seen by the author of the second treatise for more than a month. On the last day of September at 2 hours 40 minutes after sunset, by the three stars Alramech, Alfecam, and Altair, and by the torquetum, it was in Scorpio 20°, 26° north latitude, in conjunction with Mars which was then also in Scorpio 20° and moving directly. The comet subsequently moved eastward and southward and on October 6 it was in Sagittarius 1°, 10° north latitude. The motion to the east can be explained, the writer continues, by the slippage of the region of air, in which the comet was constituted, behind the celestial motion. The motion to the south was caused by the attraction of Mars which, at the comet's first appearance, was just south of the ecliptic. The tail, which was at first directed north, later moved east to south, toward the star Altair, which was at Capricorn 21°15′, 29°25′ north latitude, then gradually toward Mars.

The treatise concludes with a discussion of the significance of this comet, quotations from classical Latin poets, and a statement that providence can avert the disasters foretold.

These two brief treatises are of note because of their quantitative location of the comet and by the use of an observational instrument, the torquetum. The observation of September 30, 1301, is the earliest one that I know of that gives the time of an observation. We do not, however, have a systematic series of daily observations. The writer(s) gives careful descriptions of the tails' orientations and assumes that comets are constituted in the upper regions of the air and that their motions are to be explained by the rather sluggish participation of the áir in the daily rotation and by planetary attraction.

GEOFFREY OF MEAUX

(fl. 1310–1348)

Geoffrey of Meaux was a French physician and astrologer, active chiefly in Paris though perhaps also at Oxford. Six of his astrological treatises are extant, of which two are on the comets of 1315 and 1337 (Thorndike III: chap. 19 and appendix 19). The Latin texts of the cometary tracts, together with one on the eclipse of 1337, have been published by Thorndike (1950: chaps. 9–11). They are of interest here because they display careful attention to observation of the comet's position and course. Geoffrey and Peter of Limoges could have known one another or corresponded, but there is no direct evidence for it.

Geoffrey's treatise on the comet of 1315 begins by citing John of Damascus, Aristotle, Ptolemy, and Albumasar that comets are signs of future events, that they show a disposition or inclination rather than a necessity for ill. That this comet is not a true star is clear because it had a pròper motion toward the north pole, as can be seen by the comparison of its successive positions with the fixed stars. Geoffrey observed it from mid-December until February 12; it was visible day and night without setting because of its brightness and proximity to the north pole (less than 10° from the pole on January 15 according to Mussati (Pingré I: 427). Geoffrey followed it nightly and mentions the major stars it passed: it was with the stars in the palm of Bootes, between the two stars in Draco's tail, just below the pole, in the back of the throne of Cassiopea. He specifies the comet's positions in detail but does not give dates or times of observations. When he joined the stars which the comet passed with a great circle, he saw that this circle passed through Virgo and so assumed that the comet rose in Virgo. It was thus in conjunction with Jupiter, which was then in Virgo as well. At the time the comet first appeared, he says, Mars was in Leo, in opposition to Saturn (in Aquarius), moving retrograde; Mars then turned and was again in opposition to Saturn. Mars was the principal cause of this comet because they

were both retrograde and to the north, and the comet's tail always pointed toward Mars. Pingré (I: 426–428) reports on this comet, quoting at length from Albertini Mussati, whose account differs somewhat from Geoffrey's. Mussati said that it followed Jupiter; as Jupiter increased its latitude toward the north, the comet also climbed toward the pole. Its tail always pointed toward Jupiter. Pingré adds that this could not be true, because the sun was only in opposition with Jupiter in February, so the tail could only have been directed toward Jupiter in February. Pingré did not have Geoffrey's treatise. However, since Mars and Jupiter were in neighboring signs, and very roughly in opposition to the sun, it may not be impossible that the different astrological convictions of the observers could have distorted their rather qualitative observations this much. In the remainder of the treatise, Geoffrey deals with the comet's significance "according to the authorities".

The treatise on the comet of 1337 starts like the earlier one. By its motion we know that this is a comet, Geoffrey says, not a star or a planet. It appeared around the feast of St. John (June 24). There had been a solar eclipse in March; Mars and Saturn were then in conjunction and retrograde and thus were responsible for the generation of this comet. It was an accepted part of the cometary tradition that when superior planets are retrograde they attract vapors from the earth more than when they are direct. Geoffrey himself first saw the comet twelve days after it was first reported by others. It was then in a part of the sky without major stars, near the arctic circle, so it was difficult to assign an exact position to it. (Note that if Geoffrey had used a torquetum, instead of relying wholly on neighboring stars, this would not have presented any difficulty.) But by observing its motion he saw that it was moving directly toward the pole and, drawing great circles down from the pole, concluded that it had risen in Gemini. The observational data for this comet are not as good as those for the comet of 1315.

*

For the remainder of the fourteenth century, we find no important cometary treatises. John of Legnano wrote a treatise on the comet of 1386 but it is largely a recitation of the views of authorities (Thorndike 1950: chap. 13, text). Pingré notes many comets from the European and Chinese chronicles, but if any of these prompted theoretical treatments or good observational data, they are not extant.

COMETS IN MEDIEVAL ARABIC ASTRONOMY

There is very little observational material on comets in the Arabic sources. E. S. Kennedy (1957) collected and analyzed all the Arabic references to "tailed stars" available to him. He cites eleven sources, from the ninth to the sixteenth centuries, all of them dealing with al-Kaid, an imaginary set of objects believed to be comets. A marginal gloss to the earliest of these (829 A.D.)

refers to real comets which appeared in 1453, some other year, and 1472. In addition, Albumasar says briefly that comets are not in the sphere of fire because he himself has seen one which he knew was beyond Venus because its color was not affected. Others, he says, have seen comets beyond Jupiter and Saturn (Thorndike 1954: 22–32). Kennedy believes that this is a reference to a real comet (1957: 46); so does Lynn Thorndike, whose article Kennedy cites, and who calls this a remarkable antedating of Tycho Brahe (Thorndike 1954: 29). But Hartner is convinced that this also is a reference to al-Kaid (Hartner 1960: 504).

Hartner defines al-Kaid as "a fictitious object of planetary character, whose ephemerides are found in certain classes of Arabic manuscripts" (1960: 504). It moves in retrograde in the ecliptic with a period of 144 Persian years (one Persian year is 365 days), or about 2-1/2 degrees per year (Kennedy 1957: 45). Al-Kaid is variously described as a planet, as six or seven bodies, as a multitude of bodies, as a small cloud. (This is reminiscent of the views of Anaxagoras, Artemidorus, and Democritus mentioned above.) It apparently becomes visible when God wants to announce something of significance, usually evil. According to different sources it travels in the sphere of the sun (Kennedy 1957: 44), beyond Venus (Kennedy 1957: 46), or in the ether below the moon (Kennedy 1957: 47). Kennedy notes an uncharacteristic

> general carelessness in their handling of the numerical material related to al-Kaid. All this confirms the conclusion that the doctrine was of pre-Islamic origin and passed along as a matter of tradition. By many it was discarded, for there are no traces of it in about half the zījes [sets of astronomical tables] examined. By others, it was retained, but solely as a convenience in the casting of horoscopes. (Kennedy 1957: 51)

None of the texts discussed by Kennedy cites real observational data.

The Arabic meteorological texts discuss comets as being in the sphere of fire or the highest regions of the air. These include texts by Al-Ghazzālī, Abu Ma'shar, and 'Ali ibn Ridwan, mentioned above, who seem to accept the Aristotelian explanation of comets and not to be concerned with al-Kaid.

I have not found any references to al-Kaid in the fifteenth-century treatises, nor any allusion to Albumasar's comet beyond Venus. This is odd, because there are extant Latin manuscripts of Albumasar's treatise from the fourteenth and fifteenth centuries in Oxford, Paris, Naples, Munich, and Erfurt (Thorndike 1954: 22). But in the sixteenth century we find Maestlin and Tycho Brahe referring to the statement in Albumasar on the observation of a comet beyond Venus (Westman 1971: 55, 85; Hartner 1960). Westman and Hartner speculate that this may have suggested that comets belong to the celestial realm.

III. THE FIFTEENTH-CENTURY ASTRONOMICAL CONTEXT

Mathematical astronomy at the beginning of the fifteenth century was inherited from Ptolemy's *Almagest* as transmitted, summarized, and sometimes corrupted through the intervening centuries. The current version was Gerard of Cremona's 1175 Latin translation from the Arabic and such handbooks as al-Farghani, Campanus of Novara, and others.

In the *Almagest* Ptolemy worked out for each of the planets a geometrical model appropriate to that planet, derived the numerical parameters of the model from observations, and constructed tables which enabled the user to compute positions, in longitude and latitude, of the planets, the sun, and the moon for any given time. The tables were recomputed in the thirteenth century under the patronage of Alphonso the Wise (1252–1284) of Castille; these Alphonsine tables were the standard tool for Latin astronomers and astrologers in the late middle ages.

The geometrical models of the *Almagest* were elaborated into a physical model in Ptolemy's *Planetary Hypotheses*, his book on cosmology (Goldstein 1967). The Ptolemaic system, as it was known in the late middle ages, consisted of a nested set of concentric crystalline spheres, one for each planet, with the elemental sphere at the center and the fixed stars in the outermost sphere. In the *Almagest* the relative dimensions of each planetary model were determined but the physical reality of these models was not argued nor were they given absolute size. The absolute distances of the sun and moon were required, however, for the determination of solar eclipses, and these, were derived in the *Almagest* from measurements of lunar parallax, comparing the actual position of the moon with its theoretical position, and from measurements of solar and lunar angular diameters; the solar distance was derived from the lunar distance (Swerdlow 1968: 23–25). Ptolemy made the additional assumption that space is densely filled, that is, that the outer surface of one sphere is contiguous with the inner surface of the next, leaving no space between. He was then able to derive the dimensions of the whole system. The result, which became canonical with minor modifications in the middle ages, is summarized in the following table (Swerdlow 1968: 126):

Planet	Distance (in earth radii)	
	least	greatest
Moon	33	64
Mercury	64	166
Venus	166	1079
Sun	1160	1260
Mars	1260	8820
Jupiter	8820	14189
Saturn	14189	19865
Fixed Stars	20000	

The work of medieval cosmologers consisted of modifications of details within this general framework. It found its way to the west in the twelfth-century Latin translation of al-Farghani (fl. 850) and in Alhazen's *Cosmology*. It was the standard world picture used, for example, in Dante's *Divine Comedy*. There is no room in it for comets except in the elemental sphere.

Observational instruments which were available in the late middle ages included armillary rings, oriented to the equator or the meridian, the triquetum and quadrant (hand-held or mural) for measuring altitude angles, the armillary astrolabon and its derivative, the torquetum, for determining celestial positions in celestial coordinates, the dioptra (and its variants the cross staff, Jacob staff, or baculus) for measuring angles, and the various sundials or gnomons for measuring the position of the sun, and the camera obscura for observing eclipses. Other instruments such as the armillary sphere, albion, astrolabe, and equatorium were primarily demonstration or computing devices though they were also sometimes used for observations. These instruments and their history are described by Price (1957: 582–619). Treatises on instruments are not uncommon, (Rosińska 1974), for example those by John of Gmunden (Vogel 1963), John of Lignères (Poulle 1973), Richard of Wallingford (North 1976), and Chaucer (Price 1955).

There is not a very large corpus of astronomical observations from the middle ages. There was a tradition of observations with large instruments in Islam; observatories were established in Bagdad and Damascus in the ninth century and later in Samarkand (Hartner 1977: 6). Observations made for al-Ma'mun and by al-Battani in the ninth century, by Ibn Jounis and al-Biruni in the eleventh century, were of a standard not equalled in the Latin west until the sixteenth century (Hartner 1977: 8). In the fourteenth century Levi ben Gerson used his own observations to test and modify Ptolemy's lunar theory (Goldstein 1972: 47). Jean de Murs recorded careful observations of the sun between 1318 and 1344, including the solar eclipse of 1337 (Poulle 1973': 130). John of Lignères made his own observations in revising the Alphonsine tables (Poulle 1973: 124). The cometary observations of Peter of Limoges and Geoffrey of Meaux were discussed above, in chapter II. Some

observations appear in the treatise on the equatorium ascribed to Chaucer (Price 1955: 49, 60). But the first series of observations made systematically and over a sustained period of time seem not to have been made until the fifteenth century by Toscanelli and by Regiomontanus and Walther, and these observations were of comets or included comets.

IV. JACOBUS ANGELUS

The comet of 1402 prompted a rather lengthy treatise by Jacobus (Englehart) Angelus of Ulm. We know of him only from this treatise, which contains very little biographical information. He was probably a native of Swabia, had been in Paris in 1382, and had received many honors and benefits from the magistrates, council, and citizens of Ulm. He was a master of arts, licensed in medicine, and physician to Prince Leopold, duke of Austria. There are traces of other men of the same name during this period, in Florence, Montpellier, Paris, Vienna, but Thorndike concludes that they were different people (Thorndike IV: 81–82). He is apparently not the Florentine Jacobus Angelus who went to Constantinople to learn Greek and then translated Ptolemy's *Geography* into Latin in 1406.

The treatise is extant in manuscript form at Erfurt and in an incunabulum edition printed at Memmingen, Bavaria (not dated, but assigned a date of 1480 by Houzeau 5534; 1490 by Thorndike IV: 80, and Collard 1935: 83). Cornell University has apparently the only copy in the United States; I have worked from a xerox copy of it*.

The treatise has an introduction and ten chapters, twenty-nine printed pages in length and, in the incunabulum edition, a table of chapter headings. Jacobus states in the introduction that this treatise is simply a collection of the opinions of others and acknowledges his debt to the authorities and citizens of Ulm. The first chapter "recites the opinions of the ancients on the essence and causes of comets". His primary sources are Aristotle's *Meteorology* and Seneca's *Natural Questions*, both of which books he refers to by name, as well as Albertus Magnus and John of Damascus. He is accurate and fair in presenting their views, although he does not agree with them. He reports Seneca's opinion that a comet is a star, not of elemental nature, that approaches and recedes but is not extinguished; furthermore, that comets are among the concrete (*concretum*) works of nature, not temporary fires in the air, as can be seen from their motion and their pertinacity. Chapter two deals with meteorological phenomena in general, properties of exhalations, and characteristics of the various levels of the

* In Appendix A, p. 132–161, the edition printed at Memmingen is reproduced from a copy extant in the Jagellonian Library, Inc. B.J. 2686. (editor's note)

atmosphere; it is an essentially Aristotelian discussion. Chapter three gives in detail Aristotle's explanation of the cause and nature of comets, bringing in as supporting authorities Albertus Magnus, Constantinus, Algazel, Alpetragius, Haly, Abraham, and Albumasar.

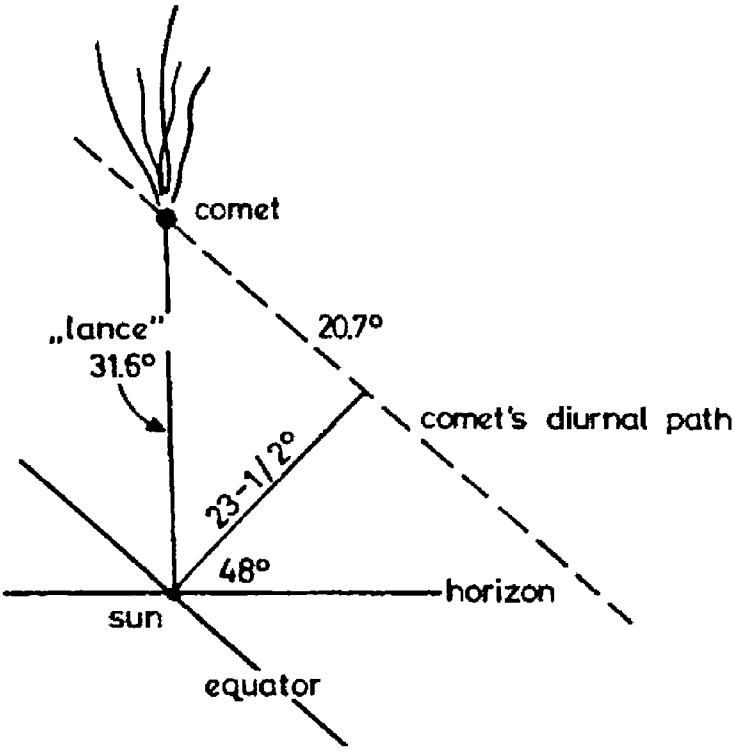
In chapter four Jacobus distinguishes five different types of exhalations, gradations from the thickest and densest to the most subtle: the two extremes, the midpoint, and two intermediate ones. This is not a very sophisticated classification system; it is that given by Albertus Magnus, though Jacobus does not identify it as such, merely saying that they are physical and natural distinctions. The astrologers, he says, distinguish nine types of comets and he gives the classification of Guido Bonatti "on the authority of Ptolemy" which are based on color and shape.

Chapter five presents the effects of comets, citing Ptolemy, Aristotle, Isidorus, and Bede. Albertus Magnus' nine types of effects are listed: death of princes, aridity, earthquakes, etc. These effects, Jacobus says, are easily explained in a physical and natural way; he then procedes to do so.

With chapter six we come finally to the comet of 1402, visible from the first of February to late March. Collard's French translation of the observation is very poor; it does not always make sense, and he simply skips difficult passages without indicating the elision. Thorndike (IV: 83) and Hellman (1944: 68–69) paraphrase the passage and also omit many portions. My translation is as follows:

> In the pontifical year 1402 A.D. around the beginning of February a comet appeared here in Swabia for many days [*multis*: to many?]. We first saw it in Ulm the fifteenth of March. On the [22nd] day it was toward the north of west, and it set crossing the horizon at the point where the sun sets when it occupies the summer solstice point. Its size [*quantitas*] was rather greater than that of Venus when it becomes visible in our hemisphere before sunrise, but not as bright [*claritas*]. Its color was the color of Venus, which is rather metallic.
>
> Its tail was for some time colored white and not very long, erected upwards, about as thick as a broom. And this tail at the beginning was inclined somewhat towards the south; later it inclined more to the south as the comet passed through the latitudes of the seventh climate [*postea magis per longitudinem septimi climatis*: see discussion below]; then the tail noticeably inclined toward the north and increased in thickness and splendor most conspicuously, so that around March 15th it appeared as long as one and a half lances, shaped like a pyramid measured linearly, whose sides came together in this comet and whose base continued toward the upper part, diffusing through the distant side of the figure. I never saw such a bright and colorful tail.
>
> And note that around the beginning of its appearance Mars was in the last third of Aries, or near there. I did not see the comet then; but later, from the place of the moon, I determined that the comet must also have been in the last third of Aries. So no one can doubt that Mars and the comet were in conjunction. Thus at some time it was true to say that a circle through the poles of the zodiac and the middle of the heaven passed through both of them.
>
> On March 22, in the second hour, it was seen near the sun at a distance of one lance to the north. Whence then it is clear that it had moved from the north through a great distance toward the south, in a direction contrary to the sun's motion [*obviando soli transversaliter*], where finally it disappeared on the feast of Easter, that is on the 26th or 27th. But in the east before sunrise its vestiges appeared, because I saw three long and very thick hairs, and after sunset I saw one hair in the west.

There are a number of difficulties with the observational data in this passage. I have tried to extract as much firm information as possible. Early in February, the comet's latitude was apparently far to the north; its longitude was in the last third of Aries, in conjunction with Mars. Tuckerman (1964) states that on February 11 Mars was at Aries 18°, and on February 21 at Aries 25°; this is at least an approximate confirmation. On



March 22, according to my reconstruction of the data, the comet's position was as shown in the diagram. Its latitude was 23-1/2° north, because it set at the point where the sun sets at summer solstice. I assume that, in the last paragraph above, "near the sun at a distance of one lance to the north", means that the comet was vertically above the sun in altitude, not in conjunction with the sun. This then gives us the longitude, the inclination of the comet's path being fixed by the latitude of Ulm, which is 48°N. The sun on March 22 was at approximately 11° longitude and very near the equator. Then a simple tangent relation tells us that the comet's longitude was about 21° greater than the sun's, or about 32°. If this is a correct interpretation of the data, we also see that a lance is about 30° in length, an interesting result. I have not seen the lance used as a unit of celestial measure anywhere, and an impromptu survey of several experts in medieval astronomy failed to turn up any other instances. A lance, which would be about six feet in length, would have to be held about twelve feet from the eye in order to subtend an arc of 30°; this seems an awkward unit of measurement. It is however quite usual to have terrestrial units of measurement translated into

generally accepted celestial measurements having no particular relevance to one another in actual size; the cubit is a good example.

The configuration for March 22 which I have derived and drawn above is consistent also with the statement that the observation was made in the second hour, that is, two hours after sunset. The comet would still have been well above the horizon and the sky quite dark.

On Easter, the comet's latitude was apparently less than 23°N; in longitude it was in conjunction with the sun, at approximately 14°. The comet's motion was retrograde and from north to south, "through a great distance".

The account of the tail is rather confusing. I interpret it to mean that the tail was at all times above the comet, so the comet was at all times north of the sun. At first the tail was deflected somewhat from straight north because the comet's longitude was somewhat greater than the sun's. As the comet moved southward, decreasing its latitude more rapidly than its longitudinal difference from the sun, the tail was further deflected from due north. But when the comet and sun were in conjunction, the tail was then straight north and at its most splendid.

My translation of the phrase *postea magis per longitudinem septimi climatis* is very free; it makes sense in the interpretation just given and does not make sense to me otherwise. The seventh climate refers to the geographical region between certain terrestrial latitudes; there are different traditions for the boundaries between the climates: according to Ptolemaic tradition, the seventh climate is 48°–90°N; according to Arabic tradition it is 45°–48°N or 47°–50°N (Honigmann 1929: 161). "Through the entire length, or extent, of the seventh climate" then I suppose must mean "through the celestial latitudes which correspond to this terrestrial zone". *Magis* I take to refer to the inclination toward the south, that being the immediately preceding descriptive term. It might also refer to an increase in size or brightness, but my interpretation is reinforced by the fact that the following phrase also refers to the tail's inclination. Collard, Thorndike, and Hellman all omit this clause entirely, without comment or ellipsis marks.

Jacobus did not observe directly that the comet was in conjunction with Mars. He evidently determined the comet's longitude by comparing its position to that of the moon, whose longitude he knew, and then determined that previously the comet had been in the last third of Aries. He must have extrapolated back from its observed motion. It is apparent, however, that he wanted to find this result, because of the traditionally assumed astrological relationship between Mars and comets.

This passage, then, contains more observational data than is immediately apparent, but it is not very systematically presented. The positional data are inferior to those given by Peter of Limoges and Geoffrey of Meaux in the preceding century.

Chapter seven begins to deal with the comet's significance; its effect

depends, Jacobus says, on the quality, quantity, proximity, and duration of the terrestrial exhalations. This present exhalation had been building up for some time and Jacobus describes three unusual meteorological phenomena, in 1399, 1400, and 1401, which gave evidence of the accumulating vapors; they all occurred in Swabia, which shows that the effects of this comet will be most pronounced in Swabia. Astrologers determine the area to be affected by a comet from the direction of its tail, Jacobus continues in chapter eight. According to them, effects will be strongest in *longitudinem septimi climatis*, the same designation given in the observational passage quoted above. In this case, the astrologers, arguing from the direction of the tail, reach the same conclusions about the areas to be most affected as does Jacobus, arguing from other meteorological evidence. Jacobus then recalls that the comet of 1382 was followed in 1385 by three great conjunctions in a short space of time: Saturn and Jupiter on April 11 in Gemini 26°; Mars and Saturn, June 15 in Cancer 4°; and Jupiter and Mars, June 28 in Cancer 12°. And 1385 was a year of multiple ills. He therefore is fearful of what will happen because this comet will be followed in 1405 on January 12 near noon by a conjunction of Saturn and Jupiter. (Tuckerman confirms these conjunctions.)

Chapter nine is devoted to comets in the past and the dire events which followed their appearances. Jacobus points out that effects need not be immediate, in fact may lag behind the appearance by as much as six years. Thorndike has transcribed a long selection from this chapter on the events of 1382–1385 as Appendix 41 in his *History of Magic and Experimental Science* (IV: 662–664).

The tenth and final chapter advises faithful Catholics (*sic*) to disregard this and other astrological predictions and to place their faith in God. The colophon says: "This treatise was compiled and completed by Jacobus Angelus of Ulm, master of arts and licentiate in medicine. Physician to the illustrious prince, Archduke Leopold, duke of Austria".

Pingré (I: 447–449) presents the often conflicting testimonies of the chronicles on this comet. He does not cite Jacobus' treatise. Some reports claimed that it was visible all night, which Pingré says was impossible, except perhaps at the very end of its appearance. There are incompatible statements about the orientation of the tail, the period of visibility, and the location. On Palm Sunday, March 19, and the two succeeding days, according to one report, its increase in size and brightness was prodigious; by Tuesday the 21st, its tail was 200 "brasses" in length. (A "brasse" is a linear unit of about six feet, here used as a celestial unit of undefined size. If we make this 200 brasses equivalent to the 1-1/2 lances maximum length reported by Jacobus, we see that a brasse is equal to about 1/5°. I can find no confirmation of the size of this unit.) During the eight days following the 21st, the comet was seen during the day near the sun. Pingré believes that this is the same comet as that of 1661.

This comet does not appear in the catalogs of Brian Marsden (1975) or Hermann Mucke (1972). Observational data are not secure enough for computation of its orbit. An attempt was made by the author of the Astronomical Column of "Nature" in 1887, based on the data in Pingré but not specifying which of the conflicting data he used; he obtained the following: perihelion, March 21; longitude, 208°; ascending node, 117°; inclination, 55°; least distance, 0.38 astronomical units; direct motion. The author, perhaps John Russell Hind (Vsekhsvyatskii 1964: 100), claimed that these elements represented the comet's motion well enough but did not account for its spectacular brightness ([Hind] 1887).

V. PAOLO TOSCANELLI

There is very little direct evidence about Paolo Toscanelli's life and work. A manuscript of cometary observations with a contemporary attribution to him was discovered in the Biblioteca Nazionale in Florence in 1864 (Banco Rari 30). It aroused considerable interest and in 1894 a monumental work, *La vita e i tempi di Paolo dal Pozzo Toscanelli*, was published by Gustavo Uzielli, including a chapter on the cometary observations and Toscanelli's astronomical work in general by the astronomer Giovanni Celoria. This work by Uzielli collected all the available sources and has been the foundation for all subsequent work on Toscanelli.

Critical examination of Uzielli's sources reveals their paucity. Thanks to a grant from the Renaissance Society of America, I was able to work in Florence for six weeks during the summer of 1976 and to attempt to track down the original documents in Florentine libraries and archives. Apart from the manuscript BR 30, we have tax records for the Toscanelli family, Paolo's registration with the physicians' guild, and his death record. Beyond this, we have admiring references to him by some of his contemporaries, dedications to him of works by Regiomontanus, Nicholas of Cusa, and Leon Battista Alberti, brief biographies by Vespasiano da Bisticci and Bernardino Baldi, a eulogy by Ugolino Verino, and a reference to him in Vasari's *Lives of the Artists*. Parronchi has recently attributed an anonymous treatise on perspective to him. No other writings by Toscanelli are known to survive and there is no contemporary reference to his interest in comets.

Uzielli's work is part of the *Raccolti dalla Comissione Colombiana* commemorating the quadricentennial of Columbus' discovery of the new world, because of the famous correspondence between Toscanelli and Columbus which included a map of the route to the Indies. Neither the original letters nor the map has survived, only sixteenth-century transcriptions and translations of the letters. The authenticity of the entire correspondence was challenged by Vignaud (1902) but modern historians seem to accept it as genuine though erroneous and misleading. This is discussed further below.

The documented facts of Toscanelli's life are few. He was born in 1379. Paolo and his older brother Piero registered with the physicians' guild in Florence in 1425; their registration fee was waived because their father, Domenicho, was a physician (Archivio degli Arti). According to the family

tax returns (Catasti), they were prosperous, owning a substantial house in town and many properties in the countryside. Paolo never married but lived in the households of his father, his brother (who had thirteen children), and finally his nephews. He died on May 10, 1482 (Libro de morti).

Contemporary or near-contemporary sources give us a picture of Toscanelli as an admired physician, mathematician, astronomer, astrologer, and geographer. He was a member of humanistic circles and a close friend of Nicholas of Cusa and Brunelleschi.

A brief biography of Toscanelli (Vespasiano 1963: 423 – 424) is included among the biographies by Vespasiano da Bisticci (1421 – 1498), a copyist in Florence with a sizeable workshop, frequented by scholars and politicians. With the advent of printing, Vespasiano's business fell off and he retired to the country to write his memoirs and the biographies of illustrious men of his time. According to him, Toscanelli was learned in Greek, Latin, and geometry, was modest and religious, and "most people held him to be a virgin". He was a vegetarian and "thought less of riches than of virtue". He apparently only practiced medicine for the benefit of his friends, spending most of his time studying and conversing with his friends. He was an astrologer, "slow in giving an opinion, but should a friend ask for information in his science, he would receive it". The word for "opinion" in the original is *iudicium* or *giudizio*, which here should probably be translated in its astrological sense as judgment. There is no mention of Toscanelli's interest in comets.

References to Paolo in others of Vespasiano's biographies tell us that he was one of a group of humanists who met daily at the Camaldolese convent of Friar Ambrogio, a group which included Cosimo and Lorenzo de Medici and Nicolao Nicoli. He practised astrology with Cosimo (Vespasiano 1963: 223). When Nicoli died in 1437, he left his collection of over 800 volumes of Greek and Latin texts to San Marco for public use; Toscanelli was at his deathbed and was named as one of the overseers of the library (Vespasiano 1963: 401).

Some time after Toscanelli's death, Vasari (1511 – 1571) referred to him in his *Lives of the Artists*. In his *Life* of Brunelleschi he said that Brunelleschi met Toscanelli at a dinner party and became his student in mathematics and life-long friend. From this reference Uzielli construes an active collaboration between the two men on the construction of the Duomo, fruitful marriage of mathematician and engineer. In the cupola of the Duomo there is a gnomon for measuring the maximum elevation of the sun at summer solstice; this has been plausibly attributed to Toscanelli by Ximenes (1757) and others, but there seems to be no contemporary documentation in the archives of the works of the Duomo or elsewhere. The friendship of Brunelleschi and Toscanelli is a major piece of evidence for Toscanelli's authorship of the instrument.

The gnomon consists of a bronze disc mounted horizontally on the sill

of the southern window in the cupola. At summer solstice the sun beam passing through a hole in the disc hits the floor of the cathedral in the north transept; there is a marble disc embedded in the pavement labelled 12 June 1510, and a smaller unlabelled disc which Ximenes says is from 1468, when Toscanelli "must" have made the observation. Ximenes gives details of the construction of the gnomon and of his reconstruction of it which he used to make observations in 1755. He was at pains to prove the excellence of the instrument and of Toscanelli as an astronomer both to assert the primacy of Italian astronomy and to establish the value of the earlier observations for his own astronomical calculations, exactly as Celoria was to do with the cometary observations some century and a half later.

In the early sixteenth century the gnomon was used as a check on the stability of the dome and cupola: if they shifted the sun beam would no longer coincide with the disc embedded in the floor. But Celoria (1921: 64) states positively that it was erected as an astronomical instrument for measuring the obliquity of the ecliptic and the motion of the eighth sphere, and that it was with this gnomon that Toscanelli made the determination of the obliquity of the ecliptic referred to by Regiomontanus (see below). To get the obliquity of the ecliptic from the maximum elevation of the sun, he would have had to have an independent vaule for the latitude of Florence. To have any hold at all on the motion of the eighth sphere, or precession, he would have had to have an independent value for the latitude of Florence. solstice, impossible with such an instrument as this, and to have made a series of observations over a long period of time. With the information at hand, it is not possible to state positively what the original purpose of the gnomon was, nor who its author was.

In June 1977 a group of historians and astronomers from the observatory at Arcetri (just outside Florence) attempted to reproduce the observation of the summer solstice using Toscanelli's gnomon. (This was reported to me by T. Settle in a private communication, and in articles in *La Nazione*, June 20, 23, 29, 1977.) It was cloudy on midsummers day, but on June 23 at 1: 17 the image of the sun, about a meter in diameter, the size of the large marble disc embedded in the pavement, crossed the meridian line. The press reported that this experiment confirmed the stability of the dome, which has been of some concern recently because of traffic vibrations and earthquakes.

Vasari painted the only extant portrait of Toscanelli. It is part of a mural depicting illustrious Florentines in the room of Cosimo il Vecchio in the palazzo della Signoria. Vasari copied the portrait from one in Santa Trinita by Alessio Baldovinetti done in 1470–1471; this original painting no longer exists, but Vasari's is reproduced as the frontispiece of Uzielli's *Vita*.

Uzielli (1892: 199) stated that Toscanelli was the principal astrologer consulted by the Florentine government during the entire mid-century.The evidence for this is a reference in the *Archivio Storico Italiano* that a maestro Paolo is the only one named of a group of astrologers consulted for the most

auspicious day to confer authority on the Captain General for the Republic, 28 September 1453 (Casanova 1891). A "casa dell'Astrologo" which was located in the piazza of the Duomo accordingly must have belonged to Toscanelli and must have been where he kept his books and instruments while he was working on the construction of the gnomon, and must have been where the Signoria came to consult him (Uzielli 1893: 36). The conclusions drawn by Uzielli seem much too strong for the evidence.

Around the middle of the fifteenth century we find some rather more convincing traces of Toscanelli. Nicholas of Cusa (1401–1464) dedicated to Toscanelli two of his works, *De geometricis transmutationibus* (ca. 1450) and *De arithmeticis complementis* (ca. 1451), and made him one of the interlocutors of his dialogue on the squaring of the circle (1457; Schmeidler 1972: 426–428). By his own testimony, Nicholas' friendship with Toscanelli dated from his adolescence. According to Uzielli's reconstruction, this could only have been while Nicholas was a student at Padua, between 1417 and 1424. This, then, is the evidence that Toscanelli received his medical education at Padua during the same time. The friendship was life long; Toscanelli was at Nicholas' deathbed and witnessed his will.

In 1464 Regiomontanus wrote a treatise attacking Nicholas' work on squaring the circle and addressed it to Toscanelli (Regiomontanus: appendix to *De triangulis* 1533; Schmeidler 1972: 417–510). In his dedication Regiomontanus hyperbolically compares Toscanelli to Archimedes: "you possess all the disciplines in such perfection that if you wanted to measure yourself with Archimedes, you might win the palm" (Garin's translation 1972: 130). Garin states that Regiomontanus wrote two letters to Toscanelli. I have not found them; Zinner does not mention them; and I suppose that Garin is referring rather to the dedicatory passages in the attack on Nicholas (Schmeidler 1972: 445, 472).

Regiomontanus did refer to a determination of the obliquity of the ecliptic made by Toscanelli and Alberti in a letter to Giovanni Bianchini, February 1464 (text in Murr 1786: 148). Regiomontanus said of them, "sepe audivi dicentes", which Uzielli takes as absolute proof that the three men were close friends (Uzielli 1894: 285).

Alberti also dedicated one of his works, the *Intercenali*, to Toscanelli (Garin 1972: 120). These dedications and references are at least evidence of Toscanelli's contemporary reputation as a mathematician. Unfortunately nothing of his mathematical work survives apart from some calculations in the manuscript BR 30 (see below). A brief letter to Nicholas of Cusa referred to by Garin (1972: 140) apparently has no mathematical content; I have not been able to find the letter and Uzielli does not mention it.

Toscanelli's astrological activities are referred to by other contemporaries in addition to Vespasiano. There seems to be some disagreement over how seriously he believed in astrology, which was then an integral part of both

medical practice and astronomy. There are clearly astrological sections in the manuscript BR 30. Yet both Pico della Mirandola (1463–1494) and Marsilio Ficino (1433–1499) reported that Toscanelli was an unbeliever, or at least sceptic, because at 85, though he had outlived all his kin, he could find nothing in his own horoscope that foretold a long life (Garin 1972: 138; Celoria 1921: 58). But Lucio Bellanti, countering Pico, claimed that there was nothing Toscanelli had greather faith in (Garin 1972: 139). It may be, as Celoria postulates, that Toscanelli's views on astrology changed during his lifetime. It is certainly true that the astrologer Toscanelli was an embarrassment to the historians Ximenes, Uzielli, and Celoria.

Bernardino Baldi (1553–1617) wrote a series of biographies of illustrious mathematicians of the fifteenth and sixteenth centuries. Collections of these biographies were frequently published (Baldi 1707, for example), but Toscanelli's existed only in manuscript until 1884 when Uzielli published it. The biography of Toscanelli, written in 1589, does not add anything new to what we already know. Baldi noted the high esteem in which Toscanelli was held by Nicholas of Cusa and by Regiomontanus, and quoted Regiomontanus' comparison of Toscanelli with Archimedes, adding however that this may have been intended ironically. Baldi also stated that, as far as he knew, Toscanelli had left no works for posterity, further evidence that the cometary manuscript was not known by his contemporaries.

Uzielli's book is part of the collection of documents and studies by the Colombiana Commission for the 400th anniversary of the discovery of America because of Toscanelli's alleged correspondence with Columbus on the western route to the Indies. Toscanelli is supposed have written in 1474 to the Portuguese canon Fernam Martins, whom he had met at the deathbed of Nicholas of Cusa, stating that the way west to the Indies was short, and enclosing a map. These documents were transmitted to Columbus who corresponded directly with Toscanelli on the subject, and used the Florentine's authority in presenting his arguments for the voyages. The correspondence and map have been lost though early sixteenth-century transcriptions and translations are extant. A map grid and list of cities with their geographic coordinates are part of the manuscript BR 30 and were used by Uzielli to reconstruct the missing map (Uzielli 1894: chap. 7). Uzielli claimed for Toscanelli the title: "initiator of the discovery of America" (Uzielli 1892).

Vignaud in 1902 claimed that the entire correspondence was fraudulent, that Columbus himself had never referred to the map or letters, and that they were fabrications, probably by Columbus' brother Bartholomew with the complicity of the historian Las Casas (1474–1566), to counter charges that Columbus had merely followed the instructions of a pilot who had made the voyage previously, and to prove that the discovery of the new world was based on the rational application of scientific principles. A heated dispute

followed. Recent historians including Morison (1942), Garin (1972), and Abetti (1952) seem to accept the correspondence as genuine. Garin states (1972: 136): "Whether the correspondence between Columbus and Toscanelli is authentic or not, it is certain that Columbus was acquainted with Toscanelli's idea [...]. Thus Columbus turned the mistaken measures of the geographers into the true reality through a fruitful joining of knowledge and action". But if the correspondence is not genuine, there is no evidence that Toscanelli had any such ideas.

Toscanelli died on May 10, 1482 (Libro de morti). Uzielli says that he deposited a notarized list of his books and instruments with the prior of San Marco and that by a notarized testament he left dowries to his nieces and his books, including sixteen volumes in Greek, or the proceeds from their sale, to his nephews (Uzielli 1894: 589–590). Uzielli collected these documents among others and intended to publish them (Uzielli 1894: 659) but, so far as I have been able to determine, never did so. I was unable to find the list among the records of San Marco and could not locate the will.

Ugolino Verino (1438–1516) wrote a eulogy in verse which was not published until 1893 (Uzielli 1893: 16). In addition to rather elaborate praise of Toscanelli as a physician, geographer, mathematician, and astronomer, he stated that Toscanelli had written treatises on perspective and on agricultural astrology, and that he had revised or repeated (*retexit*) Ptolemy's great work. An anonymous treatise on perspective which had previously been attributed to Alberti has recently been published and attributed to Toscanelli, on rather unconvincing grounds, by Alessandro Parronchi (1964: 583–641). The other treatises referred to by Verino have not turned up. Verino does not mention Toscanelli's interest in comets.

Italian and even Florentine chauvinism is everywhere evident in Uzielli's work, as indeed it is in Celoria's. That Columbus is thought to have had Regiomontanus' ephemerides with him evidently rankled, and both these Italian scholars take pains to prove that the Italian, Toscanelli, was earlier, better, and more influential than the German, Regiomontanus, not only in the matter of geographical exploration but in his astronomical work in general, particularly in his research on comets. Thus Celoria (1921: 67, my translation):

> It has been said of Regiomontanus that he worked to give life back to astronomy, which the barbarism of the preceding centuries had cast in the shadow of profoundest ignorance; that he did the only exact observations to achieve his grand design; that he did not spare his vigils; that he studied the sky in the sky itself. I do not deny this, but it can even better be said of Paolo dal Pozzo Toscanelli. He, even before Regiomontanus, without sparing vigil, studied the sky in the sky; before Regiomontanus, Toscanelli had with a firm and wise hand, placed astronomy on the fruitful road of exact observation and from him Regiomontanus learned much, by his own admission [presumbly in the letter to Bianchini].

But he did not publish, and so effectively vanished from the history of astronomy until the late nineteenth century.

DESCRIPTION OF MANUSCRIPT BANCO RARI 30

The manuscript (Bibl. Naz. Florence) is a collection of loose pages of various sizes. They had at one time been bound into a volume of which they formed folios 237–258 under the old designation of Magliabech class XI, n° 121. The manuscript was separated from the rest of the volume at some time, Garin (1972: 125) says in the nineteenth century, and restored April 26, 1972, after the flood of 1967. There are fifteen sheets in all plus three modern cover sheets, one of which gives a not very accurate inventory of the contents of the manuscript. The manuscript is on beautiful heavy-weight cream paper with well-defined watermarks. The basic page size is 44.5 × 30 cm.; some were used full-size, some were folded in half, some were cut to half-size, and some are of irregular size and shape. There are five different watermarks (see plate I). They are written in at least two different hands, in light brown or blackish-brown ink, and a number of pages have faint pencil markings and engraved markings which do not show in microfilm or Xerox reproduction. The engraved markings were made with a drypoint, a smooth, sharp point which made indentations in the paper without leaving any pigment (as with a ball-point pen which has run dry); they are visible in oblique light and with infra-red photography. I believe that these markings are contemporary with the writing of the manuscript.

The order of pages as they were bound in the book was not rational, and retaining that ordering seems pointless and confusing. I have decided, therefore, to order the pages for the most part chronologically and by handwriting. The physical characteristics of the manuscript are summarized in the following table:

fol. n°	contents	pg. size (cm)	hand	water-mark	pencil or engraving
237	1456 } Avogaro	22 × 30	S	none	no
235	1456 } Treatise	44.5 × 30	S	A	no
244	Immensi labores	22 × 30	S'	A	no
245	1433	14.7 × 22	T	A*	no
249	1433	14 × 19, × 23	T	D	yes
242	1449–1450	22 × 19	T	C	yes
250	1449–1450	44.5 × 30	T	C	yes
246	1456	14.7 × 22	T	A*	no
252	1456, 1457-II	22 × 30	T	A	yes
257	1456	44.5 × 30	T	A	yes
240	1457	45 × 30	T	B	yes
239	1457-II	22 × 30	T	A	yes
247	1472	11 × 15	T	none	no
254	cities	44.5 × 30	T	E	no
253	map grid	44.5 × 30	T	D	no

* these two pages were once one half-size page; the cut is through the watermark; the page was cut before it was used

I have gone through the manuscript carefully, with Celoria's analysis and transcriptions at hand. I have numerous small differences of opinion as to transcription, many notes of features of the manuscript itself which he either did not notice or did not comment on, and a discovery of two series of observations of the comets of 1456 and 1457-II on fol. 252 which he apparently overlooked entirely. After a few preliminary remarks about the handwriting, I will go through each page in turn. Because the manuscript as a whole has not been published and is quite inaccessible, I will discuss it at greater length and in more detail than the importance of its contents perhaps warrants, and reproduce the pages as I discuss them.

HANDWRITING

Folios 237, 235, and 244 are in a handwriting clearly different from that of the remainder of the manuscript, although Celoria thinks that they are the same (Celoria 1921: 22). I have designated the first hand as S (for Somebody else) in the table above, and the second hand as T (for Toscanelli, since I believe it is his). It is possible that fol. 244 is in a hand different from the others (S'); there are both similarities and differences. Uzielli proposed that S was one of Toscanelli's nephews, pressed into service as a scribe.

In the state archives in Florence there are tax returns prepared by individual taxpayers for the special income taxes called Catasti. I have examined the Catasto Portate for 1427, 1430, 1433, 1446, 1457, and 1480, all of the Catasti during Toscanelli's lifetime for which I found returns for the family of Domenicho di Piero Medico. They are fascinating documents, listing all of the family assets, properties, liabilities — — whether debtors were good risks, bad risks, or hopeless — — and family members with their ages and relationships. The returns were prepared in the name of the head of household, Domenicho, while he lived, then Piero, Paolo's older brother, then finally Paolo and his nephews.

But the handwriting in the returns of 1427, 1430, and 1433 is unquestionably the same as T of the manuscript, and that of 1446 is probably also the same; there is a slight difference in this last one, the page having a somewhat more precise look, though a detailed comparison of individual words and letters did not turn up any differences at all. The watermarks on the 1427 and 1430 returns match watermarks C and D of the manuscript. These Catasto volumes are arranged by neighborhood, and there are other returns from the quartiere S. Spirito which have these same watermarks. On the bottom of fol. 489 v in the Catasto of 1427 there is an addition in a quite different hand, rather wavering, like an old person's hand, claiming an exemption for medical books and adding a couple of debtors. I suppose that the returns were prepared by Paolo, and that Domenicho checked them over and made this addendum.

The 1457 return is in a completely different hand. It has some resemblance to the hand S of the manuscript, but I am not willing to state positively that it is the same. In 1457 Paolo would have been sixty, his oldest nephew thirty-two. Folios 237 and 235 are from 1456, or at least are transcriptions of documents from 1456. The 1480 return is in yet another hand and on completely different and much larger paper.

Nowhere in the tax returns is the name Toscanelli used. The ages and biographical information concur with what is known about Paolo Toscanelli, but this is hardly surprising since Uzielli used these tax returns as his primary source. The location of the house described in the returns is on a street at the end of which was a well (*pozzo* or *puteo*) called Toscanelli, or of Tuscany (Uzielli 1884: 7); there was in that neighborhood a Via del Pozzo Toscanelli, though it did not coincide with the present Via Toscanelli, also in the same neighborhood.

On the Piazza Pitti today there is a large house which backs onto the present Via Toscanelli and which bears a large plaque stating:

Paolo dal Pozzo Toscanelli
Astronomo matematico geografico medico filosofo
fondatore nel duomo dell antico gnomone
ingegno universale
che per osservazione celesti e studi cosmografica divinatore
inizio la scoperta del nuovo mondo
visse anni LXXXV di vita integerrima
dal MCCCLXXXXVII al MCCCCLXXXII
in queste case de suoi
che il commune di Firenze
insignisce del nome de lui
MDCCCLXXXXVIII

This is due to Uzielli and is considerably toned down from what he initially proposed (1894: 609–610).

Although Uzielli used the Catasti as a source for biographical material, he did not explicitly use handwriting analysis to confirm the attribution of the manuscript BR 30 to Toscanelli, nor is the handwriting discussed by Celoria. Both of these scholars seem to have accepted absolutely the attribution of authorship. Until I noticed the coincidence of handwriting and watermarks, however, I had been rather sceptical, particularly since the attribution of f. 235 to Toscanelli seemed to me patently erroneous (see discussion below). In fact, there were moments during my researches in Florence when I believed that Paolo Toscanelli was entirely a fabrication of nineteenth-century historians.

FOLIO 237

Fol. 237 r, v (see plates II, III) contains a copy of a document signed by Petrus Bonus Avogarius, astrologer at the University of Ferrara, dated 17 June 1456. Celoria's transcription (1921: 21) follows, with some very minor changes by me indicated in brackets:

† Iesus

Stelle cum caudis secundum Ptolemeum in libro Centum verborum novem sunt, quarum nomina sunt ista. prima Veru dicitur, secunda Tenaculum, 3a Pertica, 4a Miles, 5a Dominus Ascone, 6a Mattutina, sive Aurora, 7a Argentum, 8a Rosa, 9a Nigra. quarum quatuor prime assimilantur stellis, et omnes significant bella et terrores et magnos eventos in mundo, et ex colore earum cognoscetur malum in mundo futurum, et ex natura signi in quo primo apparent et [vel] cum quo oriuntur scitur quando malum accidens erit. ex predictis nature cometis in presenti unus ascendit cum signo Tauri sub polo Artico, et parum declinat versus orientem, et caudam erigit inter austrum et orientem, et celum mediat cum signo Geminorum, cuius cum Ptolemeo a Saturni et Martis et parum Mercurii viribus non recedunt, cui etiam tria sunt nomina in diversis temporis spatiis, videlicet in principio, in medio, et in fine sui ortus. in principio ortus Rosa est, in medio Dominus Ascone, et in fine Nigra, oritur autem sphera Saturno exeunte in domo Martis et Marte in domo tenebrarum cum cauda Draconis. significat enim stella ista comata secundum Ptolemeum mortem regum et divitum magnatum et nobilium et eorum qui regno sunt subiecti, et eventus magnarum rerum, et ipsarum apparitionem et aliarum rerum antiquarum que mutabuntur ad melius, et mutabuntur res mundane et venient meliores, et in parte in qua apparet cauda, videlicet in oriente et meridie, inducit mortem regum et guerras et mortem multam et decollationem et mortalitatem et mortem naturalem et mortem per gladium. et quia, in adventu solis ad primum minutum Cancri cometa oritur cum Cancro et equidistat signo Geminorum, ut scribat Albumasar tractatu 5o/ differentia 7a significat casum guerrarum et rumorum terribilium in terris Romanorum et Babillonie, et significat quod advenient civibus Babillonie egritudines vehementes, et erit cum eis anonna pauca, et incurrent cives Italie infortunium, et consequentur oppressionem et mortalitatem. significat etiam quod ex terremotu quedam pars terro desolabitur, et quod erit frigus vehemens in hieme [hyeme] et corruptio messium in anno sequenti. et quia apparet ex parte orientis, significat quod rex Turcorum timebit de inimicis, et quod cadent bubones in homines illius regionis vel mortalites [mortalitates] et durabunt annis sequentibus. et quia etiam apparet in equidistantia Geminorum, signifient quod rex Romanorum habebit angustias multas et infortunia, et quod rex Egypti morietur, et regnabit post ipsum fur qui non erit de Egyptiis, et erunt egritudines et mortalitates et fames et mors puerorum et abortus [aborsus] pregnantium et mors avium et tonitura magna et corruscationes, et comburentur fructus, et quia apparet in oriente, multi magnates cadent de ordinibus suis et, secundum Haly, libro 8 capitulo 41, morietur rex Christianorum, et erunt interfectiones et guerre in terra Babillonie, et multe civitates in terris Christianorum depopulabuntur. morientur Taurini et civitates Taurine ab epidemia [epidimia] non evadent ex cometa cum Tauro ascendente. civitates autem et provincie Taurine sunt: Campania magna, Benomia, Scne, Verona, Ancona, Tarvisium, secundum aliquos Mantua. Asti, Senegalia, Persaurum &c. Die 17 Iunii 1456. *Petrus Bonus Avogarius.*

This document does not contain any observational data except in very general terms. It names the nine kinds of comets, according to Ptolemy's *Centiloquy*, he says, and goes on to detail the significance of this comet according to the same source. As we have seen above, these are not in fact from Ptolemy, but from the medieval tradition of Ptolemy on comets. There

is no attempt to localize the effects of the comet, to make them applicable, for example, to Florence.

Celoria calls this a letter from Avogaro, but it has none of the rather elaborate stylized greeting and closing phrases characteristic of letters of this period. It is, rather, a brief tract of a very conventional kind, prompted by the appearance of the comet of 1456.

Thorndike (IV: 464) alludes to this treatise but says, "The text is now missing, as is a work by Toscanelli on the comet of 1456 which is listed in a table of contents on the fly leaf as formerly found at fol. 237. But see our chapter 57, notes 67–75". These notes refer to the Toscanelli manuscript as analyzed by Celoria. Some confusion on Thorndike's part is evident.

FOLIO 235

This is the first page of a work (see plate IV) which was to have had five chapters. It breaks off in mid-sentence at the bottom of the page, more as if a copyist quit work than as if the author did not finish the treatise. The verso is blank. Celoria's transcription (1921: 22), with my corrections in brackets, is as follows:

† Iesus

Ex precepto quorundam maiorum meorum decrevi breviter aliquid iudicare super isto cometa noviter viso et faciam 5 capitula. primum quo modo vocatur iste cometa et in quo signo et loco visus sit. secundum quid sit cometa et unde et quale [qualiter] causatio sit. tertium quod indicare [iudicare] habeat. quartum in quo loco et in qua parte mundi habeant apparere eius effectus. quintum et ultimum quantum durare habeant et quando initium dabunt indicata [iudicata] per eum. unde ad primum incipiendo dico.

Quod anno Christi currente 1456 die 6a iunii hora 6a noctis sequentis apparuit cometa qui vocatur Tenaculum secundum Ptolemeum in primo sui Centiloquii, sed eum vidi 14a iunii hora 6a noctis videlicet per duas horas ante solis ortum, quia in aurora disparuit. et est ex colore Martis, habens crines seu [ceu] comam in modus fumi subcineritii, et apparuit in dorso imaginis que vocatur Aleyer [Alcyor], tenens habenas circa vigesimum [20m] gradum signi [sigm not in text] Geminorum, et est imago septentrionalis habens 14 stellas, quarum una lucidior primo magnitudinis et est super sinistram spatulam et vocatur Yreus [Yrcus], et alia 2e magnitudinis super spatulam dextram, et 7 sunt 4e magnitudinis, et due earum sunt tertie magnitudinis, et due [2e] 5e magnitudinis, et una 6e magnitudinis. et omnes stelle istius imaginis sunt de natura et complexione Martis et Mercurii, et omnes iste sunt in signo Geminorum. et oriebatur dictus cometa cum signo Tauri in quo erant Mars et Venus, et apparuit prima vice et simile [similiter] quando eum vidi inter grecum et septentrionem, et potius versus grecum, videlicet ad partem orietalem [orientalem], elevatus a nostre horizonte fere per 16 videlicet eius corpus cum cauda seu coma, se extendens sursum versus locum Martis qui tuac [tunc] reperiebatur in xo grado Tauri et movebatur parum ad motum diurnum firmamenti, et est de natura et complexione Martis et Mercurii, sed die 15a iunii...

The style of this folio is quite different from that of the preceding one. The sentences are more direct and it is much easier to read. The opening paragraph sets out the contents of the five chapters. The body of the work

then begins with observational data giving the date and time of the comet's appearance (my translation):

> In the sixth hour of the night following June 6, 1456, a comet appeared, of the type called Tenaculum according to the first book of Ptolemy's *Centiloquy*. But I saw it June 14th, the sixth hour of the night, visible for two hours before sunrise, when it disappeared with the dawn. It is of the color of Mars with a smoky tail or coma, and it appeared in the back of the constellation Alcyor. [Description of the stars in that constellation] And this comet rose with the sign of Taurus in which Mars and Venus were. It appeared first and also when I saw it between the northeast and north, and rather towards the northeast, toward the eastern part, elevated from our horizon by about 16 [degrees]. Its body with the tail or coma extended upwards towards the place of Mars which then was in the 10th degree of Taurus, and it moved less than by the daily motion of the firmament. It is of the nature and complexion of Mars and Mercury. But on the 15th of June...

Celoria states quite positively that this treatise fragment is by Toscanelli. Note, however, that it says, "in the sixth hour of the night following June 6, 1456, a comet appeared [...]. But I saw it June 14th, the sixth hour of the night..." This is odd considering that the observations recorded on fol. 246 of this manuscript begin on June 8, and through June 16 are noted at hour 7 of the night. Celoria does not remark on this apparent inconsistency, but it suggests to me that this is rather another transcription, like the Avogaro document. Garin (1972: 139) says, "This incomplete treatise has been attributed to Toscanelli (Uzielli–Celoria, *La vita*..., p. 327), but without serious grounds. Moreover, in concept it resembles an analogous writing on the comet of 1472 contained in the same codex (Magliab. 11: 121, c. 235r), and it is no coincidence that it should initially have been combined with Avogaro's writings".

Folios 237 and 235 were the first two of this collection, as bound in the Magliabech codex, followed by the chart on fol. 240 of the comet of 1457-II, and followed only five pages later by the attribution to Toscanelli. It is certainly plausible that they were unrelated to the other pages, included only accidentally or mistakenly. Garin (1972: 132) states that the motive for separating this manuscript from the remainder of the codex was to dissociate the pure scientist Toscanelli from the superstitious astrology of the surrounding documents. These two folios are, however, astrological, and should, according to Garin's explanation, have been excluded, particularly since they are in a quite different hand. This question could probably more easily be resolved if the Magliabech codex could be reconstructed and comparisons made both of the handwritings and of the contents of the surrounding treatises.

FOLIO 244

Fol. 244 (see plate V) contains the single sentence "Immensi labores et graves vigilis magistri Pauli de puteo Toscanello super mensure comete"; "With boundless labor and burdensome wakefullness, by Paulo of the Toscanelli

well, on the measurement of the comet". The verso is blank. This is the only indication of authorship of these pages. That this is a contemporary attribution is suggested, though not proved, by the watermark, which matches that of several others in the manuscript, and the handwriting, probably the same as that of folios 237 and 235 which are dated 1456 (though this date is not necessarily the date of transcription.) Celoria (1921: 61) makes a great deal of the word "mensura", emphasizing that these are measurements, not merely qualitative observations.

FOLIO 245

This appears at first to be a page of random calculations (see plate VI). Celoria (1921: 6) addresses himself only to the words; attention to the calculations themselves, however, reveals some interesting information on Toscanelli's mathematical and astronomical sophistication. It is, as noted above, the only evidence of his mathematical work apart from testimonies from admirers. A detailed analysis of these calculations has been published (Jervis 1979). It is reproduced in Appendix B. Here I will present only a summary. For convenience in discussion I have marked sections of the page and numbered them:

1. a long multiplication problem in sexagesimals
2. a long division problem in sexagesimals
3. a small eccentric diagram
4. two sextuples of numbers which fit the Menelaos theorem
5. a decimal multiplication using numbers from the Menelaos configuration in section 4, rounded off
6. another approximation to the same problem as section 5
7. two sextuples of numbers, again for a Menelaos configuration
8. other sets of numbers, suggestively arranged, but whose relationships I have not been able to determine
9. a list of numbers, several of which appear elsewhere on the page; no operation is indicated
10. an addition problem
11. an addition problem
12. an addition problem
13. an addition problem
14. a list of numbers
15. a table of observations made, apparently, with a baculus.

I believe that this is a page of computations, used perhaps in teaching, in which sample problems of sexagesimal arithmetic are worked out and examples of the Menelaos theorems are set up. Whether the numbers used in these problems are related to some particular problem in astronomy is not clear; there are enough regularities or repetitions of numbers to suggest that they

are not just random numbers. If Toscanelli were choosing numbers just for demonstration purposes, I would think that the chords, for example, would all be numbers taken directly from a table of chords, not requiring interpolation, or that an interpolation problem would appear among the computations.

Section 15 contains an observation of Jupiter on 13 November 1433. This is after the period in which he was making observations of the comet of 1433 (October 3–31). According to Tuckerman, Jupiter on 15 November 1433 was at longitude 140.75, latitude 0.82, which would make the latitude on 13 November about 0.48, 36, not so very far off from Toscanelli's 0.44, 45. But the relationship of this observation to the other numbers in this section is not at all clear.

FOLIOS 245v, 248r: COMET OF 1433

At the top of fol. 245v and in the lower right, there are tables of numbers which seem to be unrelated to the cometary observations (see plate VII). An analysis of these tables is given in Appendix B. With the center portion of this page we come finally to Toscanelli's cometary observations (Jervis 1977). The brief paragraph was transcribed by Celoria (1921: 6) as follows, with my corrections in brackets:

apparuit comata [*sic*] stella mihi primo die dominico 4[a] octobris 1433 in die sancti Francisci prima hora noctis in imagine corone Adriane versus eius partem meridionalem, ut in figura patet. visa tamen fuit ab alio, quomodo ex quodam scivi [quomodo ad meum scivi] die sabati precedente 3[a] octobris. die 5 octobris lune in secundo visa est extra Coronam in parte meridionali magis aliquantulum; hac die visa est magis clare [clara], prima enim die visa est [delete est] satis plumbea, nescio an hoc erat quia aer non ita serenus fuit sicut hac die [sicut dies], et etiam cauda in obscuritate noctis videbatur longior. magnitudo eius erat sicut stellarum secunde magnitudinis sed non tante claritatis.

Or, in my translation:

The comet first appeared to me on Sunday, October 4, 1433 on the day of St. Francis, first hour of the night, in the constellation Corona Ariadne toward its southern part, as shown in the figure. However it was seen by others, as was made known to me, the preceding Saturday, October 3. On Monday, October 5, its second appearance, it was outside the Corona a little bit more on the southern side; that day it appeared brighter, for the first day it appeared rather leaden. I do not know whether this was beacuse the air was not so clear. The tail was seen longer in the darkness of night. Its magnitude was of a second magnitude star but not as brilliant.

The figure of the Corona with the positions of the comet on October 3, 4, 5, and 6 should be considered as a unit with the chart of fol. 249, (see plate VIII), which contains observations from October 14 through 31. A page of observations is missing; the observations for October 7 through 13 would have occupied a page just about the size of f. 245. On the right-hand edge of f. 248 there are three small chicken's-feet markings which look very much like register marks to align this page with an adjoining one. Several engraved lines through fixed

stars and through the cometary positions of October 14–17 also run right off the edge of f. 249 as do the tails from October 14 and 15. There are, however, no alignment marks on the left edge of f. 245 v, nor does the tail of the missing October 7th comet extend onto f. 245 v, as it should if this were a direct extension of the missing page.

The stars of the Corona on f. 245 v are arranged on a circle drawn with a compass; the hole at the center is clearly visible. Two diameters are ruled without pigment through α and ε Coronae, and a star diametrically opposite ε Coronae was drawn and then erased. There is no sign on this page of a grid or scale. The stars are located on the circle of the Corona from the right, counter-clockwise, at approximately 36, 128, 180, 212, 238, 270, 308, and 348 degrees. I had hoped that the angular positions of the stars on the circle might correspond to the small table of numbers just to the right designated a, b, a, a, b, but they do not appear to; none of the stars is at 45 or 60 degrees from either axis, though perhaps close enough to have been put on by eye.

There are few fixed stars on f. 249 r; these few are all connected by engraved lines. Again on this page there is no sign of any grid or scale. The page is of irregular shape. The comet's positions are not connected by alignment markings with any of the fixed stars though there is a line through the first four positions which continues across to the vicinity of the October 21 position, the comet having deviated from this straight line. The positions march across these two pages very regularly, evenly spaced, and with very little deviation from a smooth path. The positions for October 28–30 are indicated only with points; presumably Toscanelli did not see it on those nights, but on the 31st it was precisely where expected. The most striking feature of these observations is the delineation of the comet's tail, much more clearly visible on the original than on the microfilm copy. The tail varies from over 8 cm. in length on October 16 to a mere smudge on October 31.

The overall appearance of these pages suggests that these are not precise daily observations, each made independently of the others with respect to fixed stars or to any other framework, but that they are indications of the general path of the comet, and that the phenomenon of particular interest to Toscanelli was the comet's tail, not its precise position. In astrological tradition, the direction of the tail was an important indicator of the geographic region to be affected. It was not until the 1530s that it was recognized that the tail always pointed away from the sun (see chapter VIII below).

This is quite contrary to Celoria's evaluation of the same data. He uses these diagrams to obtain very precise positional data for this comet and to determine the comet's orbit (Celoria 1921: 9). Using modern positions for the stars along the comet's path, Celoria plots them according to a gnomonic projection, obtaining a chart which agrees very well with Toscanelli's charts. He then puts the cometary positions in place using his own alignments with the

stars on Toscanelli's charts, though, as I would like to emphasize again, there is no indication on the manuscript that alignments between the comet and fixed stars were used by Toscanelli himself — — only from one fixed star to another and from one cometary position to another. This is quite different from the charts for the comet of 1449–1450, which we will come to presently. Celoria then calculates the comet's positions from his charts, using the positions of October 5, 20, and 31 as key reference positions because their alignment with fixed stars seems most secure.

To find the times of observation, which Toscanelli does not give precisely for this comet, Celoria determines:

1. The "first hour of the night", or the time of sunset plus the duration of civil twilight, when the comet might first be visible.
2. The time the comet set.
3. The probable time of observation, taken by Celoria to be the mid-point between these two times. This is clearly an approximation. Celoria states, however, that since the comet's proper motion in one hour during the period October 4–6 was 1'3" right ascension, 3'0" declination, and during the period October 20–31 was 0'8" right ascension, 3'8" declination, the error is negligible. For October 31, the time of setting for the comet would have been 6: 23 p.m., which corresponds with Toscanelli's notation, "prima hora noctis occidit".
4. These times reduced to the Paris meridian.
5. The position of the sun for each of these times of observation.

This information is sufficient for Celoria to have computed the parabolic element of the orbit, from which he calculated an ephemeris (1921: 9) which agrees well with Toscanelli's charts and with European and Chinese chronicles.

FOLIOS 242 r, 250 r: COMET OF 1449–1450

These two folios (see plates IX, X) form a unit containing observations from December 26, 1449 through February 13, 1450. They reveal clearly a new style of observation and charting, rather different from that used in 1433. The last three observations on f. 242 r, January 7, 8, and 9, overlap the first three on fol. 250 r. Folio 250 was originally one page, cut in half; the chart was drawn on the two portions which should be aligned as indicated by the left hand of Bootes. As well as the inked markings on these pages, there are a number of markings in very faint pencil and engraved without pigment. A number of the fixed stars were pencilled in and then inked over and the constellation figures were also pencil-sketched first; this is particularly clear in the Serpent. On these pages there are no alignments indicated between fixed stars. There is no scale or grid indication, and it is not evident how the fixed stars were located on the charts.

Toward the bottom of the page is located a star marked "Jupiter 14g

?6m Sagittarius"; Tuckerman gives the position of Jupiter for 21 December 1449 as longitude 254.12, latitude 0.49, a very close agreement. Venus is also indicated at 2g10m Sagittarius; Tuckerman gives the position of Venus for 26 December 1449 as longitude 243.13, latitude 2.19.

Once the stars were in place on the chart, however, it is very clear how the cometary positions were determined. The first position is labelled "comet day 26 December 1449 approximately in longitude with Jupiter, in latitude more to the north". The first four positions, for December 26 through 29, are placed on the page by means of alignments with the fixed stars, drawn free-hand and in ink, each position being on the intersection of two such alignments. The lines are rather wobbly and uneven and the resulting positions do not form a smooth path. Celoria says (1921: 11, my translation):

> But perhaps because this method of alignment is lacking in security, perhaps because of an apparent deformation of the constellations produced by being observed low and near the horizon, perhaps as an effect of imprecise measurement, the positions of the comet designated on this chart follow a serpentine line and inspire some doubt as to their precision.
>
> On [f. 250], Toscanelli abandoned the system of alignments and returned to that which he had followed for the comet of 1433. He returned, that is, either to drawing by eye from the real, or to measuring, calculating, and drawing from these repeated measurements; he returned, I repeat, to depicting the relative positions of the comet and the principal stars through which it passed, marking next to each cometary position the day and sometimes even the hour of observation, and conserving, in placing the stars on the chart, their exact relative positions in a way that makes their identification easy and secure.

He did no such thing. This is clear if we take seriously the engraved lines which are visible on the manuscript, though not on the microfilm; they are, I hope, faintly visible on the reproduction given here, which was taken from an infrared photograph of the manuscript page. What Toscanelli did was to stop making his alignments free-hand and in ink and to start making them more precisely with a straight-edge. If, in fact, we take a straight-edge and straighten out the free-hand lines, the path smooths out somewhat. The positions for January 1 through 9 which are on f. 242 all lie on these engraved alignments, most of them on the intersection of two such alignments. One of the lines, through the comet on January 4, extends off the edge of the page and has the notation, "to the second magnitude star in this direction", a notation which makes no sense at all if we ignore the alignment indication. The ink on the star to the left of the January 7 position is smeared by the engraved line connecting it with the January 1 position; conclusive evidence that the engraved lines are contemporary with the writing of the manuscript.

For the first of January there is the notation, "altitude of the comet 26g 30, altitude of Cor Scorpio 9g"; this would give him the precise time of observation. The observation for January 4 was at "about the 14th hour"; for January 6, the "13th hour, altitude 42". Times of observation are not noted for January 7 through 16; then on January 17 there are two observations, one at hour 9 and one at hour 12. Thereafter there is a time noted for every observation; on January the hour is given as 9-2/3.

I sense in this series of observations a continuing effort to make more precise the determination of the comet's position, without a very clear idea on Toscanelli's part of the best way to go about it. The times, for example, given in general as the number of whole hours from sunset, could be given more precisely by the altitude of a known star, but this is done only once, January 1, and indirectly for January 6, and the time is not explicitly derived from the stellar altitude.

Just beside the position of the comet on December 26, the first observation, there are the two numbers 32−1/2 and 40. I do not know what these refer to.

It is curious that on f. 242 the dates are given as December 1449 and January 1450. It was at this time absolutely standard practice in Florence that the year began on March 25, the day of the Annunciation. This system is in fact known as the calculus Florentinus (Ginzel 1958: III, 161), and I have not been able to find any other instance in Florentine documents of a year change on January 1. Professor Gino Corti of Florence, specialist in medieval and renaissance Tuscan manuscripts, knows of no other instance, and feels that this is an anomaly which should be explained (personal communication). Toscanelli was consistent in this; the comets of 1457-I and 1472 were in January of those years, under the modern convention. Toscanelli was probably following the convention of his astronomical tables.

Celoria (1921: 10−20) analyzed the data in these charts in a manner analogous to that described above for the comet of 1433, and derived orbital elements and ephemerides which are consistent with notices in the European and Chinese chronicles.

FOLIOS 246 r, v, 252 r, 257 r, v: COMET OF 1456

Toscanelli gives a wealth of information on this comet, Halley's comet, in several different forms. Another change in his observational and charting techniques is evident. He apparently used star catalogs with stellar longitude and latitude and probably had an instrument which enabled him to take observations directly in longitude and latitude, perhaps a torquetum or some kind of armillary sphere. Again I have the impression that he was searching for greater precision and a more complete description of the comet's position and motion but was not yet sure of the best technique.

Fol. 246 (see plate XI) has a little bit of everything on it. At the top of the recto there are verbal observations as follows (Celoria's transcription 1921: 22):

> Die iovis 17 iunii hora 2a noctis cometa videbatur in occidente altitudine [altitudinis] gradus 1 40 distans versus septentrionem a vero occidente gradus 56. fuit in Cancro secundum longitudinem gradus 12 30 minuta et secundum latitudinem gradu ab ecliptica versus septentrionem gradus 14 10 minuta.
>
> Die sabati 19 iunii hora 2 34 minuta noctis altitudo comete 1 40 distantia a vero occidente

versus septentrionem gradus 51-1/2. videbatur in Cancro 24 gradus 50 minuta et secundum latitudinem septentrionalem 15 gradus 20 minuta.

Die dominico 20 iunii hora 1 26 noctis altitudo comete 12 gradus 0. spica 26-1/5. tunc a vero occidente 34 gradus 30 minuta.

Or, in my translation:

Thursday, June 17, second hour of the night, the comet was seen in the west at an altitude of 1; 40 degrees, distant toward the north from true west by 56 degrees. It was in Cancer according to longitude 12; 30 degrees and according to latitude 14; 10 degrees from the ecliptic toward the north.

Saturday, June 19, 2 hours 34 minutes of the night, altitude of the comet 1; 40 degrees. 51-1/2 degrees toward the north from true west. It was seen in Cancer 24; 50 degrees and according to latitude 15; 20 degrees north.

Sunday June 20, 1 hour 26 minutes of the night, altitude of the comet 12; 0 degrees. Spica 26-1/5 degrees. Then from true west it was 34; 30 degrees.

These observations give the date, time, horizon readings, and ecliptic readings. The time given for June 17 is a whole-hour time; the times for June 19 and 20 must have been computed from stellar altitudes.

A brief paragraph headed "Per cometes fuerunt Iudicia" with the note "ex septima parte libri de Iudiciis mutationes aeris per singula superiora firmamenti" is strictly astrological in content, giving the opinions of Haly and Ptolemy on the significance of comets. This paragraph is transcribed by Celoria (1921: 23). I will not discuss it further.

On the left of the page is a table of observations covering the period June 8 through July 8, giving dates, some times, and longitude and latitude. Celoria's transcription (1921: 23) contains many errors and omissions; I give my own transcription in the table below. The comet passed perihelion on June 9, and the observations were made in the morning, hour 7, before conjunction on June 17 and in the evening thereafter. It is remarkable that Toscanelli was able to make two observations some eighteen hours apart on the day of conjunction with the sun; this was due to its rapid proper motion — — over 12° in longitude and almost 1° of latitude in a single day — — and to its large latitude of about 15° north. The longitude and latitude readings are for the most part in units of ten minutes, with just a few five-minute intervals, which suggests that his observational instrument was scaled at ten-minute intervals.

As mentioned above, the times which are given in hours and minutes are almost certainly times computed astronomically from stellar altitudes. Mechanical clocks were available in Florence at this time, but it is extremely unlikely that Toscanelli would have had one accessible to him while he was making his observations. Mechanical clocks of this period were huge, inaccurate, and likely to have only an hour hand. The clock in the Duomo today, which dates from this period (its face was painted in 1443 by Paolo Uccello), has no minute hand and is far too inaccurate for any astronomical use. So far as I have been able to determine, there was no public outdoor clock which he might have been able to see from his roof (if that is indeed

loca Comete visa				My values taken from charts		
1456	Junii die	Tauri g m	latitudo septentrional g m	g m	g m	
hora 7	8	26 30	15 0			
	9	29 20	15 25			
		Geminorum				
	10	2 0	16 0			
	11	5 0	16 15			
	12	8 0	16 40			
ditto	13	12 30	16 40			
	14	17 30	16 40			
	15	23 40	15 45			
	16	29 45	15 20	29 0	16 30	
		Cancri				
2ª noctis	17	12 30	14 10	12 30	14 10	
	18	18 40	14 50	18 40	14 50	fol. 252
2h34m	19	24 50	15 20	24 50	15 10	
		Leo				
1h26m	20	1 40	15 50	1 50	15 40	
	21					
hora 2.0	22	10 0	12 0	10 0	12 0	
	23			14 0	10 0	
	24	16 50	9 40	17 50	9 10	
	25					
1h12m	26	23 20	6 40	23 20	6 50	
	27	27 30	6 50	27 30	6 55	
		Virgo				fol. 257 r
	28	1 5	7 0	1 5	7 0	
	30	5 0	6 0	5 0	6 0	
	Iulii					
	1	6 40	5 0	6 40	5 0	
	2	8 15	4 0	8 10	4 0	
	3	9 0	3 10	9 0	3 20	
	4	10 0	2 40	10 0	2 40	
	5	11 0	2 0	10 55	2 0	
			latitudo meridional			fol. 257 v
	8	13 45	0 30	13 40	0 30	
hac die ultimo a me visa est in gradum 14 Virginis						

where he was working), though there were clocks which sounded the equinoctial hours, starting at sunset, which would have given him times like "second hour of the night".

The verso of f. 246 contains two comets labelled "day 8" and "10" and just a few fixed stars. There is not enough to identify the constellations; Celoria did not discuss this page at all. Possibly the comets represent the observations of June 8 and 10, 1456. There is no sign of a grid or scale.

Fol. 252 (see plate XII), however, has well-defined scales; the longitude down the middle of the page extends from Gemini 23° through Cancer to Leo 9°. North and south latitude scales are indicated on both ends of the page to 16°. The grid lines are strongly scored in the paper so that a square grid covers the page; the lines are not strictly parallel. This is clearly a new way of making a chart, with stars located on it according to their latitude and longitude rather than by alignment. There are no indications whatever of alignments between stars.

The edges of this page had been badly eroded, though they are now beautifully preserved through the restoration. At the very edge of the page, at about 29° Gemini, 16-1/2° N latitude, there is a dot labelled in ink "16 Iunii 1456". Celoria disregarded this or perhaps did not see it. More understandable, perhaps, is that he disregarded or did not see four more observations labelled very faintly in pencil 17, 18, 19, and 20. These positions correspond rather well to the values given in the table of f. 246 for June 16–20.

Fol. 257 r (see plate XIII) is also scored in a square grid with longitude from Cancer 27° through Virgo 10°, and latitude 10° south through 20° north, and with observations from June 20 through July 5. It is exceptional in that it has only dots, without circles around them, for the cometary positions, and no indication of the tail. Fol. 257 v also has a coordinate grid with longitude Virgo 12° through Scorpio 15° and latitude 9° south through 20° north. There is a large figure lightly sketched in, and two cometary positions only, simply labelled 5 and 8, presumably July 5 and 8, 1456. (I have not bothered to reproduce fol. 257 v.)

The three charts, then, folios 252 r and 257 r and v, make a series of observations from June 16 through July 8; perhaps fol. 246 v is the beginning of that series, giving at least June 8 and 10. I have taken the coordinates of the comet's positions from these three charts, using the grid and scale markings on those charts and estimating them by eye to ten-minute intervals. These values are given to the right of the table from fol. 246 r for purposes of comparison.

The match between Toscanelli's values from fol. 246 r and my values taken from the charts is so good that there is no question in my mind that we are dealing with the same data. The two exceptions are June 16 and June 24, which may simply be graphing errors. Celoria assumes that Toscanelli plotted the comet's positions on the charts in a manner similar to that used for the earlier comets, and that he then took the longitude and latitude values of f. 246 r from the charts. The absence of any alignment markings on these charts, however, and the fact that the tabulated values are in such nice round numbers, suggest that it is at least possible that the observations were taken with an instrument, calibrated to 10 minutes of arc, which gave readings directly in longitude and latitude. In this case, the tabulated values would be the primary observational data, and the positions were then placed on the charts as were the stellar positions. The fact that fol. 257 r has only

dots for the cometary positions seems to me to reinforce this interpretation.

Celoria devotes considerable effort to determining the probable source of Toscanelli's star positions (1921: 25–28). Of the 71 stars which appear on the charts of fols. 257 r, v (he did not include fol. 259), 64 of them appear in the *Almagest* catalog. Celoria takes the longitudes and latitudes from the charts and compares them with those of the *Almagest* and with modern values. He concludes without doubt that Toscanelli used the *Almagest* catalog transposed to his own epoch to account for precession; errors in stellar positions which appear in the *Almagest* are repeated by Toscanelli. Celoria determines that the value which Toscanelli used for the average annual precession is a little less than 52 seconds of arc, a value which he probably derived himself (1921: 28). Some of the values which were current at that time were due to Ptolemy, about 56″, to al-Battānī, about 55″, and to ibn Iounis, about 51″; the modern value is about 50.3″ (Smart 1971: 420).

The arrangement of the writing on fol. 246 r raises a number of questions. The observations recorded in the table start on June 8, but the verbal observations at the top of the page start with June 17. It is after June 20 that the entries in the table begin to be crowded together. I suspect that there was, on a page which is no longer extant, a series of verbal observations, such as we have for June 17–20 on fol. 246 r, that on the 20th Toscanelli summarized the coordinate information for these observations and thereafter recorded only the coordinates. Or perhaps this page is a clean copy of observational material recorded elsewhere and now lost.

FOLIO 240 r: COMET OF 1457-I

Toscanelli's observations of this comet extend from January 23 through 27, 1457, and appear only on fol. 240 r (see plate XIV). This page has a coordinate grid engraved on it, the longitude extending across the middle of the page from Pisces 15° to Taurus 22°, and the latitude indicated very faintly at the beginning of Aries; the latitude scale is not visible on the microfilm. The coordinate grid was rather sloppily done so that the latitude lines of the left half of the page do not exactly coincide with those on the right.

As before, Celoria (1921: 37) determines that Toscanelli had taken his stellar positions from the *Almagest* catalog. He computes the orbital elements also as before (1921: 38–39), using modern star positions, plotting the cometary positions by alignment with Toscanelli's fixed stars, and taking the probable time of observation, not given in the manuscript, as 6: 22 p.m., when the sky was dark and the comet was still fairly high.

FOLIOS 240 r, 239 r, 252: COMET OF 1457-II

The observations of this comet are scattered, on fol. 240 r, those of July 6 and 7, on fol. 239 r, July 21–27, and on fol. 252, July 28 through August 29. The two observations on fol. 240 r are in the upper left of that page; there is

a latitude scale indicated at the beginning of Taurus and a coordinate grid marked on the page. In this section of this chart there are a few faint pencil alignment markings visible between fixed stars, and a figure of a horse is faintly sketched in (it looks like Pegasus, but Pegasus is nowhere near Taurus); none of these are visible on the microfilm.

The chart of fol. 239 r (see plate XV) has a coordinate grid marked only along the right edge, where the cometary positions are, with longitude from Taurus 15° through Gemini 30° and latitude to 7° north. There are faint outlines of a figure with the comet crossing the ankle of a sandalled foot on July 22. Fol. 252, discussed above for the comet of 1456, has the positions for July 28 through August 4 and the position for August 20 recorded in ink; these are the only positions which Celoria deals with and he takes the August 20 position to be very dubious. Very faintly visible, however, are positions for August 8, 9, 18, 25, 26, and 29. These extend the previously known period of visibility of this comet by some nine days and may possibly change the previously computed orbital elements for this comet (B. Marsden, private communication).

As with the previous comets, Celoria determines that the stellar positions on these charts came from the *Almagest*, and determines the orbital elements, using modern stellar positions, aligning the comet's positions with neighboring stars, and estimating the probable time of observation.

FOLIO 247: COMET OF 1472

This is the last of the comets for which we have observations by Toscanelli, made when he was 75 years old. There are no charts, only a very small page containing verbal descriptions from January 8–26 (see plate XVI). Celoria's transcription (1921: 47) is as follows:

1472

Die 8 ianuarii mensis in nocte sequente primum visus est cometa in Libra circa 13 gradum in septentrione.

Die 9 iovis in nocte sequente vidi ego parvum cum corpore et cauda in eodem fere gradu Libre 13 latitudo.

Die 10 veneris in nocte creverat parum et motu minus quam gradu 1.

Die 14 martis in nocte notabiliter creverat.

Die 17 mane circiter decimam horam erat propinqua pro dimidio gradu ad medium trium in triangulo sinistri cruris Boetis que tunc fuit longitudinis 10 gradus 20 minuta in Libra latitudinis 26 30 quarte magnitudinis.

Die dominicho 19 iuxta cossam sinistram Boetis mtus Arturii et que sub cauda Urse in austrum tertie magnitudinis.

22 die mercurii in hora prima noctis iuxta polum mundi per 15 gradu et velocissime movebatur non potuit observari propter lumen lune et grossitiem aeris, fecit per unum circulum usque mane in quatuor diebus pertransivit totam Virginem et Leonem per brachium Boetis versus polum mundi.

23 die iovis in sero erat iuxta stellam fissam et in quatuor horis recessit ab ea plus quam per gradus 4.

24 die veneris fuit propinqua alteri stelle, credo distabat a stella in qua priori die fuit coniuncta per 20 gradus vel plures.

Die 25.

Die 26 dominico in sero visa supra corona Arietis.

Or, in my translation:

1472

The night following January 8. The comet was first seen in Libra, about 13° to the north.

The night following Thursday the 9th. I saw it small and the body and tail were in about the same degree of Libra; 13° latitude.

The night of Friday the 10th. It increased very little and moved less than 1°.

The night of Tuesday the 14th. It increased notably.

The morning of the 17th, around the 10th hour. It was within 1/2° of the middle three in the triangle of the left shin of Bootes, which was then in longitude 10°20′ Libra, in latitude 26°30′; fourth magnitude.

Sunday the 19th. Next to the left hip of Bootes within Arcturus and under the tail of the Bear, to the south. Third magnitude.

Wednesday the 22nd in the first hour of the night. It was within 15° of the north pole and was moving very quickly. It could not be observed because of the moon's light and the thickness of the air. It traced a circle until morning. In four days it traversed all of Virgo and Leo along the arm of Bootes toward the north pole.

Thursday the 23rd in the evening. It was next to a fixed star and in four hours went away from it by more than 4°.

Friday the 24th. It was next to another star. I believe it was distant from the star with which it was in conjunction the previous day by 20° or more.

The 25th day.

Sunday the 26th in the evening. It was seen above the corona of Aries.

Celoria (1921: 47) takes from these rather vague observations some firm positions. For January 17, he says, the position admits no doubt. For January 9 he takes the position to be Libra 13°, but it seems to me equally or more likely that the comet was somewhere in Libra, with a latitude of 13° to the north. He concedes, however, that using only Toscanelli's data it is possible to derive an orbit only very approximately. This leads him to consider Regiomontanus' observations for this same comet, scorning the observations of the treatise *De cometa* for their generality and lack of precision, but using the observation of January 20. (See my chapter VII for a discussion of Regiomontanus.) Celoria finally determines three sets of orbital elements using the three observations of January 9, 17, and 20, and then of January 22, analyzes them for their errors, and concludes that the second set (1921: 54) matches best with Toscanelli's and Regiomontanus' data and with reports from the Chinese and European chronicles. He is clearly dissatisfied with the quality of the data he has to work with for this comet, and has to strain rather hard to maintain Toscanelli's reputation, which he has assiduously built up, as an astronomer far ahead of his time with a sure and unfailing observer's intuition for mathematically precise data.

FOLIOS 254 r, v, 253

The remaining pages of the manuscript do not, I believe, have anything to do with comets, so I will deal with them only cursorily and do not reproduce them here. Fol. 254 r discusses nativities, time of conception, time

of birth, the duration of gestation, and the relationship of these things to the moon. The text accompanies and explains a large table; a small table gives the equation of time.

Fol. 254 v has on the left a small table of mean motions of the planets, and on the right lists of cities and their longitudes and latitudes according to several sources. Fol. 253 is a blank map grid. This grid and the list of cities are the source for the reconstruction of the famous Columbus map by Uzielli (1894: chap. 7).

These last pages are unquestionably in the same handwriting as the rest of the manuscript. They testify again to Toscanelli's interest in astrology and are the only evidence, apart from the correspondence with Columbus, of his interest in geography.

SUMMARY AND CONCLUSIONS

Careful analysis of this manuscript has revealed, I believe, a change in Toscanelli's methods of observation and charting over the almost forty years from 1433 to 1472. The changes seem to reflect a concern with finding a more accurate way of determining precise positional data for comets. In 1433, he apparently plotted his fixed star charts by transferring from another chart or according to a description of the constellations like that in Hipparchus' commentary on the *Phenomena* of Aratus and Eudoxus, which gives star positions by direction and distance from one another. This is suggested by the presence of the alignment indications between fixed stars on Toscanelli's charts and the absence of any coordinate grids on these charts. The cometary positions were then placed among the stars according, probably, to approximate alignments with the stars, though the alignments are not indicated on the chart and the smoothness and regularity of the comet's path suggest that Toscanelli was recording the general movement of the comet and that the individual observations were not truly independent of one another. The phenomenon which shows the greatest variation in this series of observations and which, therefore, may have been the phenomenon of greatest interest to him at this time, probably for astrological reasons, was the length and direction of the comet's tail.

The charts for the comet of 1449–1450 seem to show the same method of plotting the fixed stars, but the comet's positions were determined and recorded by means of precise alignments with fixed stars, most of the positions being on the intersection of two such alignments, made probably simply by holding a cord or straight-edge up between two known stars. This is the method described explicitly by Maestlin in the following century (see chapter VIII below). The very unevenness of the comet's path shows that each of the positions was determined independently of the others. From a modern point of view, this method is the best possible one; we can take modern determinations of stellar positions, and the alignments give very

secure positions. Toscanelli also rather consistently gave times of observation for this series.

From 1456 on, Toscanelli's charts have longitude and latitude coordinate scales on them and the stellar positions were taken, as established fairly convincingly by Celoria, from the *Almagest* catalog which gives the positions in longitude and latitude. Probably the cometary positions were taken with an instrument such as the torquetum which gives readings directly in longitude and latitude. This method is subject to instrumental errors due to the construction of the instrument, to its setting and alignment, and to the observer's sighting and reading.

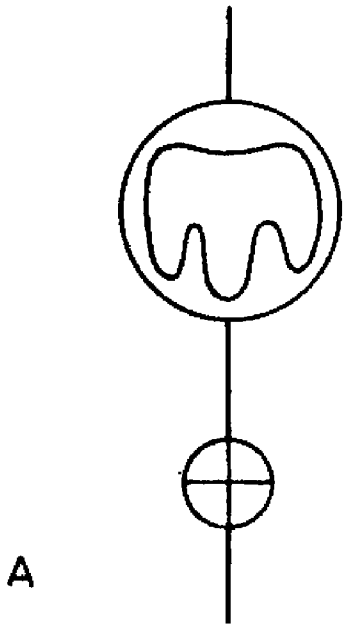
The observations of 1472 are once again rather more qualitative, more like those of 1433, though recorded in quite a different form.

It has been suggested (Price: private communication) that this series of manuscript pages may well be the earliest example of charts or maps being used as an integral part of precision measurement rather than just as pictorial representation. If so, then Toscanelli's work would be an important step in the development of cartography as well as in the history of cometary observations.

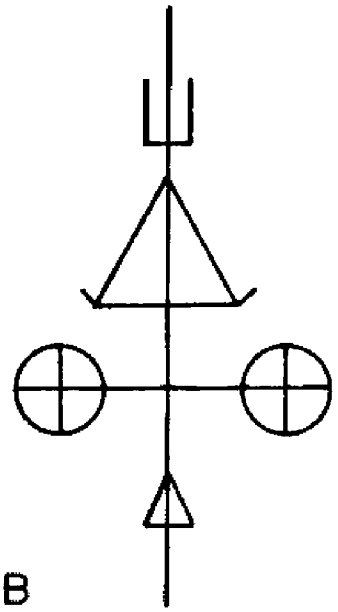
Nowhere in this manuscript is there any indication of concern with the distance of the comet from earth, the concern which was to occupy Regiomontanus and many astronomers in the sixteenth century. On January 17, 1450 (f. 250), we have two observations taken three hours apart, but there is no indication that a parallax measurement was intended; rather it seems to show a concern to record the rapid proper motion of the comet. The little diagram on folio 245 r might possibly be construed to be a parallax diagram but there is nothing to link this with comets and there is no evidence whatever that Toscanelli attempted to measure or estimate parallax on the comets he observed. There is unfortunately no accompanying text which explains Toscanelli's motivation except for the astrological excerpts on fol. 246 r associated with the comet of 1456 (if we discount the treatises on folios 237 and 238). But observations of the type recorded in these pages were not necessary for astrological purposes. That none of his contemporaries mentioned Toscanelli's interest in comets among all his other concerns is curious and suggests some secretiveness on his part.

Celoria's purposes in analyzing this manuscript were quite different from mine. As a late nineteenth-century Italian, even Tuscan, nationalist, he was passionately interested in asserting the primacy of Italian or Tuscan astronomy and mathematics, particularly over the German, and many of his effusions must be understood in that light. As an astronomer, he was interested in establishing these comets in the roster of known comets with known orbits, and for this reason also he had an interest in demonstrating the accuracy and reliability of Toscanelli's data. Thus he says (1921: 61, my translation):

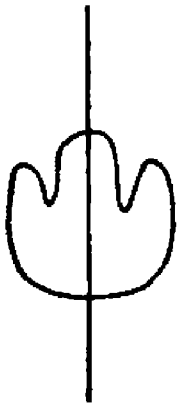
For none of the comets prior to those studied here of the fifteenth century do there exist observations comparable to these of Toscanelli, either by their number, or by the form in which they are presented, or by their intrinsic precision. [...] Toscanelli first opened the era of true cometary observation, and he opened it with a firm, secure hand, unsurpassed at his time. In the history of astronomy, this glory has been attributed to Regiomontanus until now; it is entirely Toscanelli's.



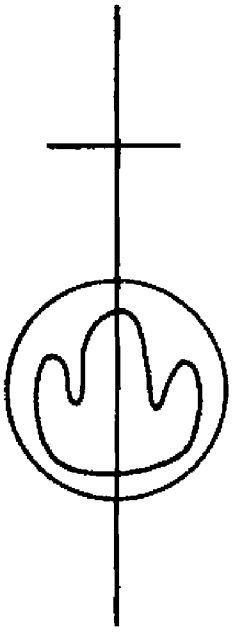
A



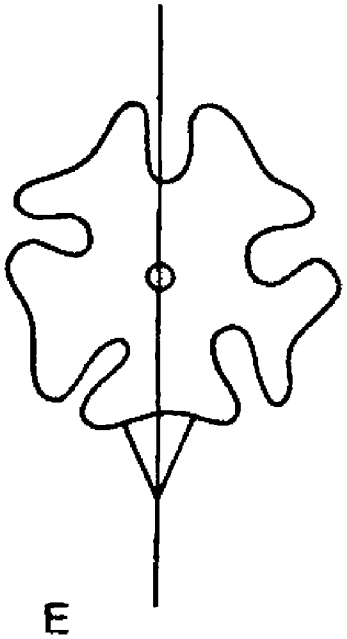
B



C

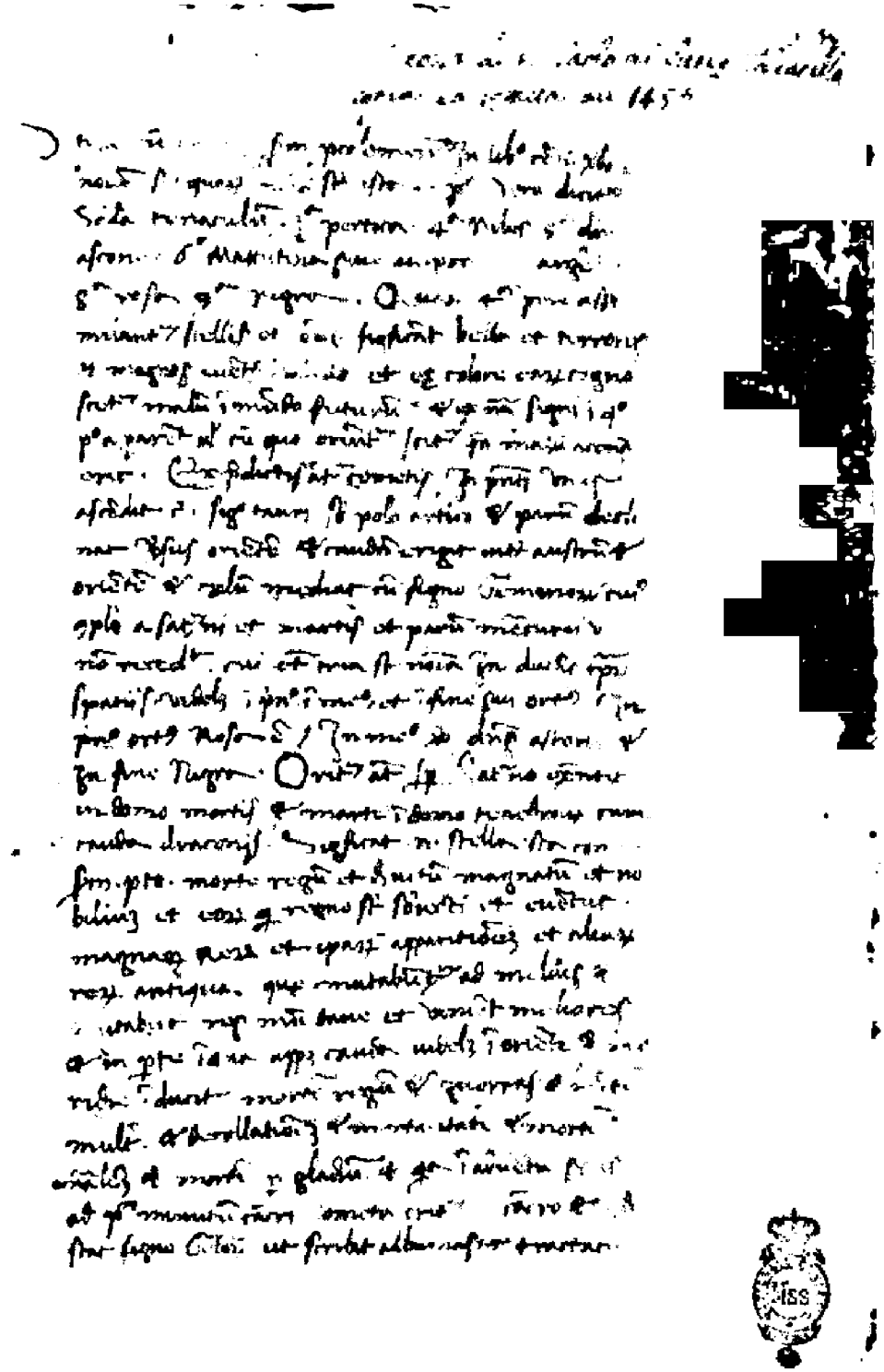


D

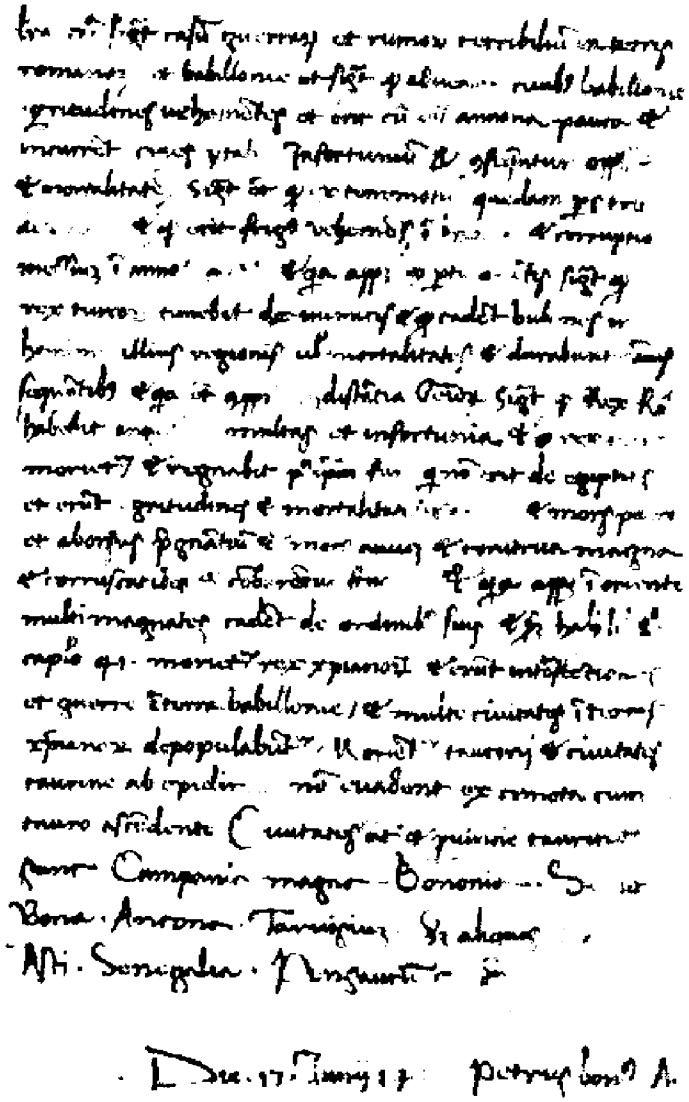


E

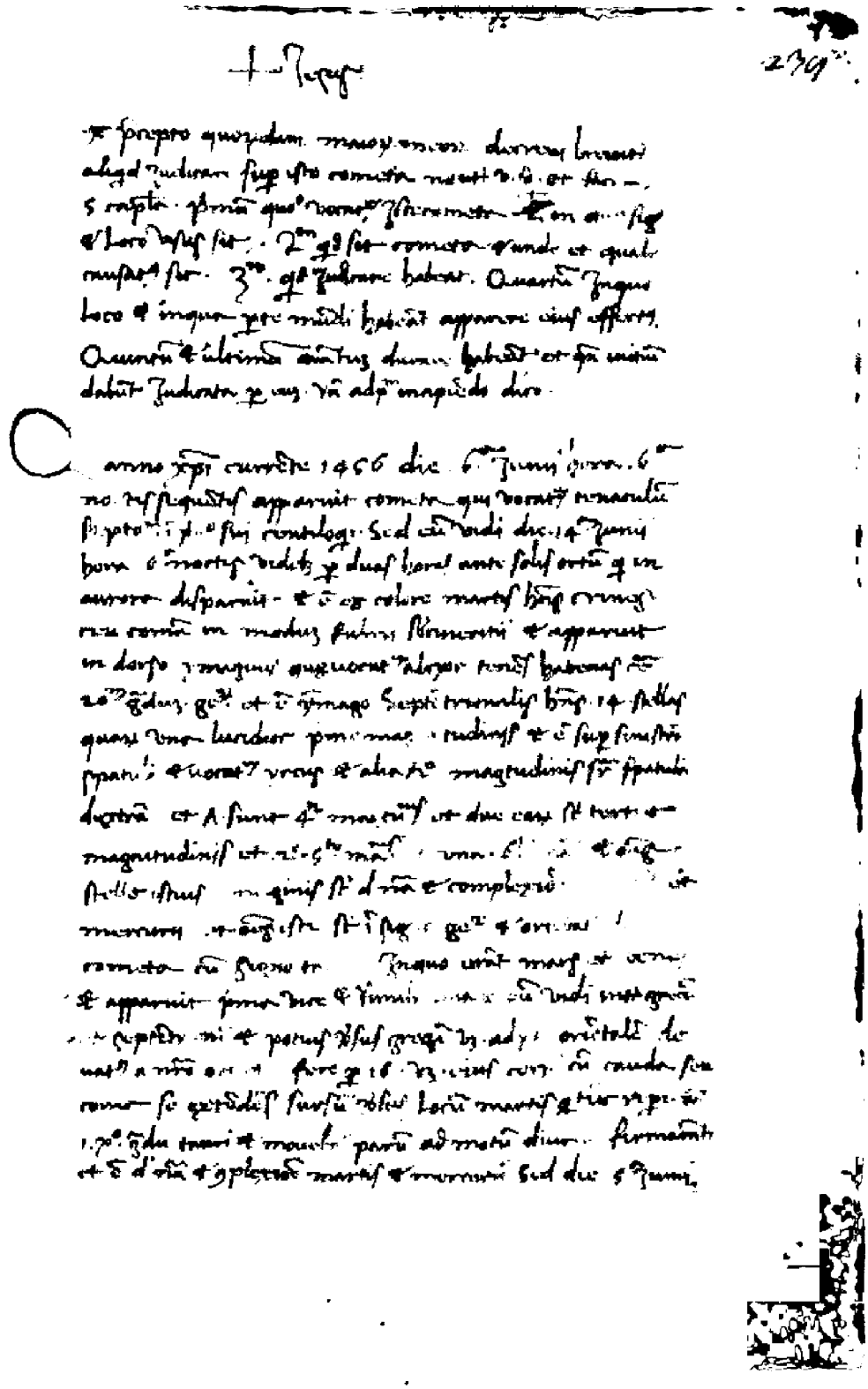
1. Watermarks.



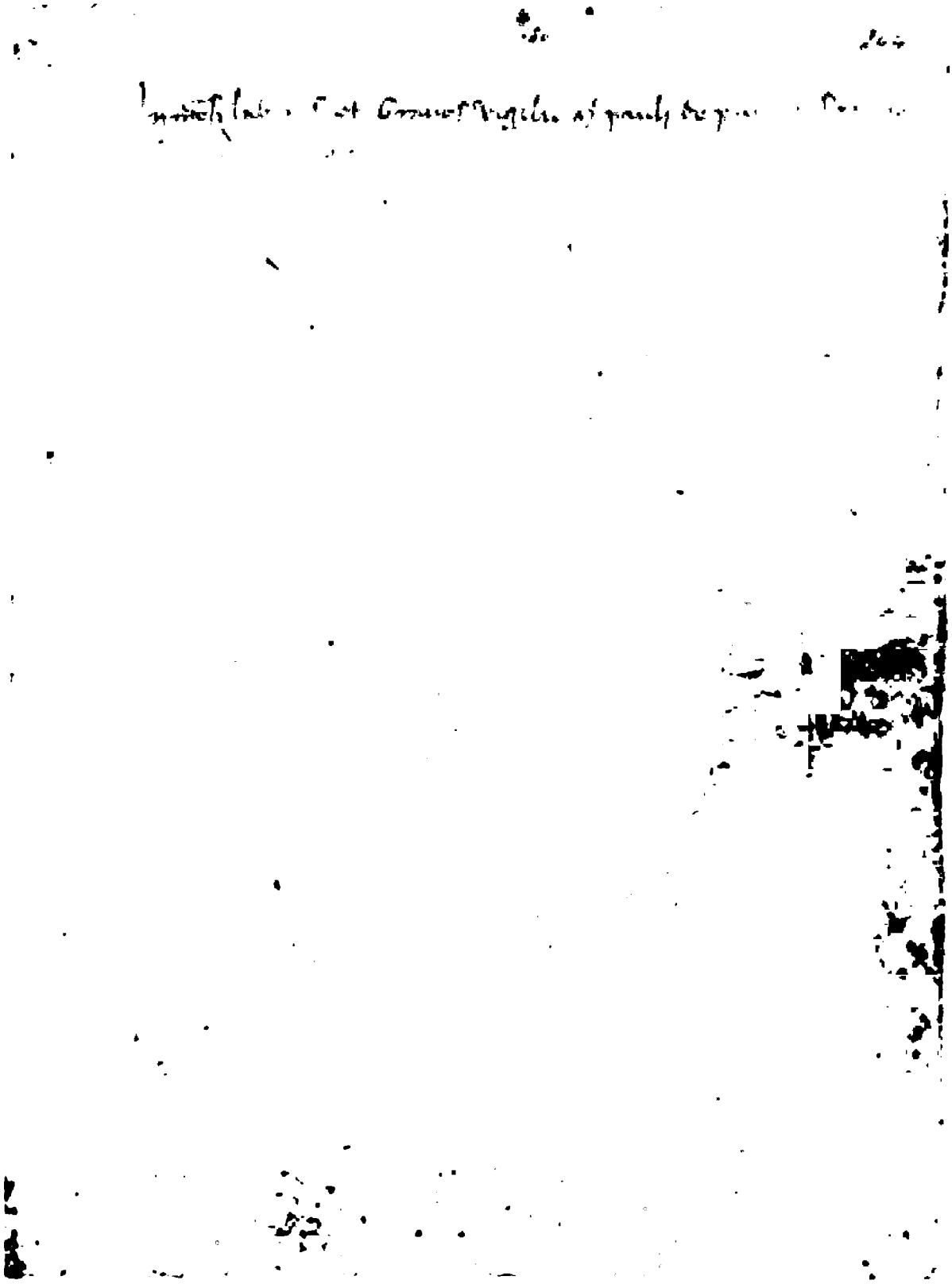
II. Folio 237 r: Avogaro Treatise on comet of 1456.



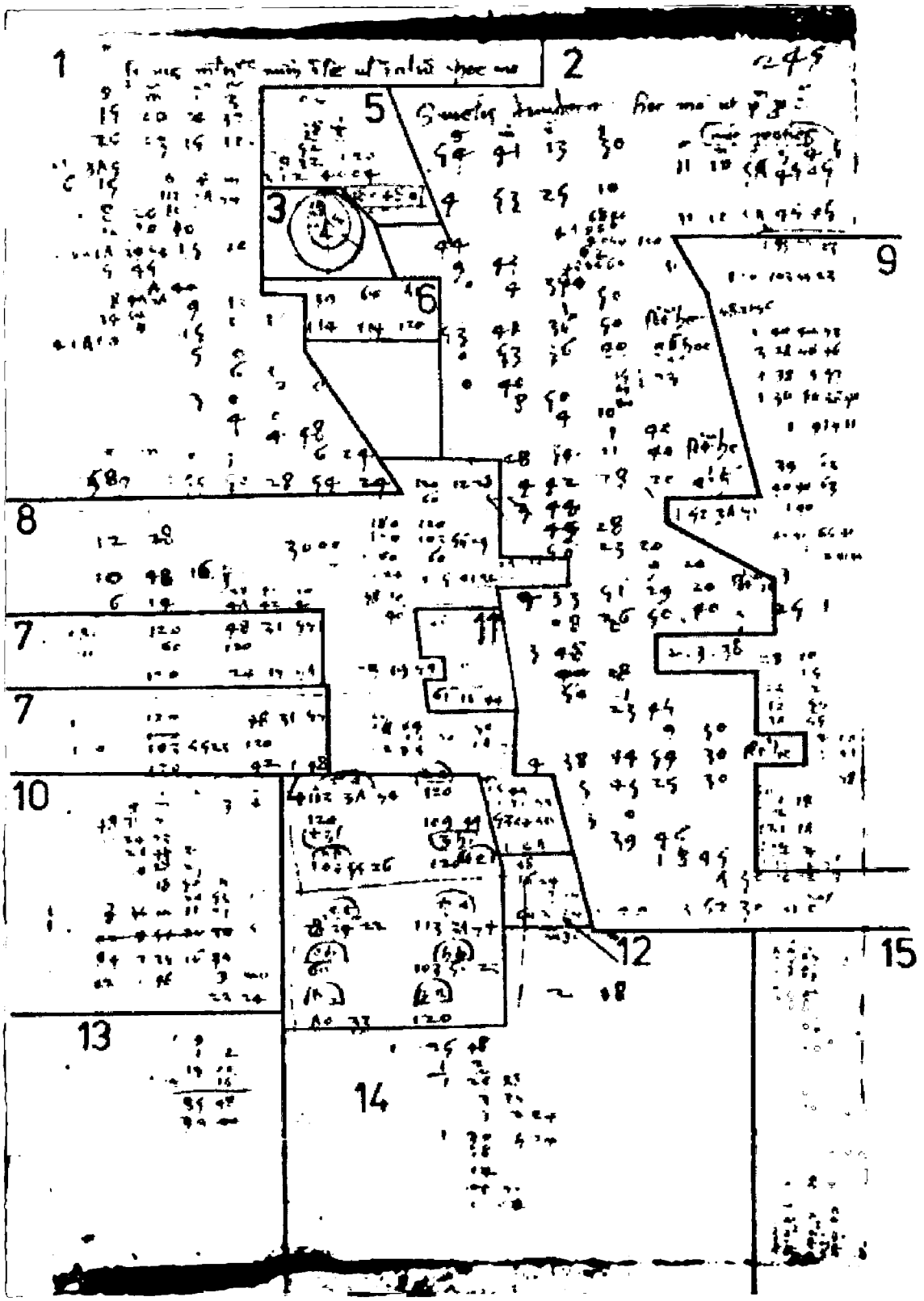
III. Folio 237 v: Avogaro Treatise on comet of 1456.



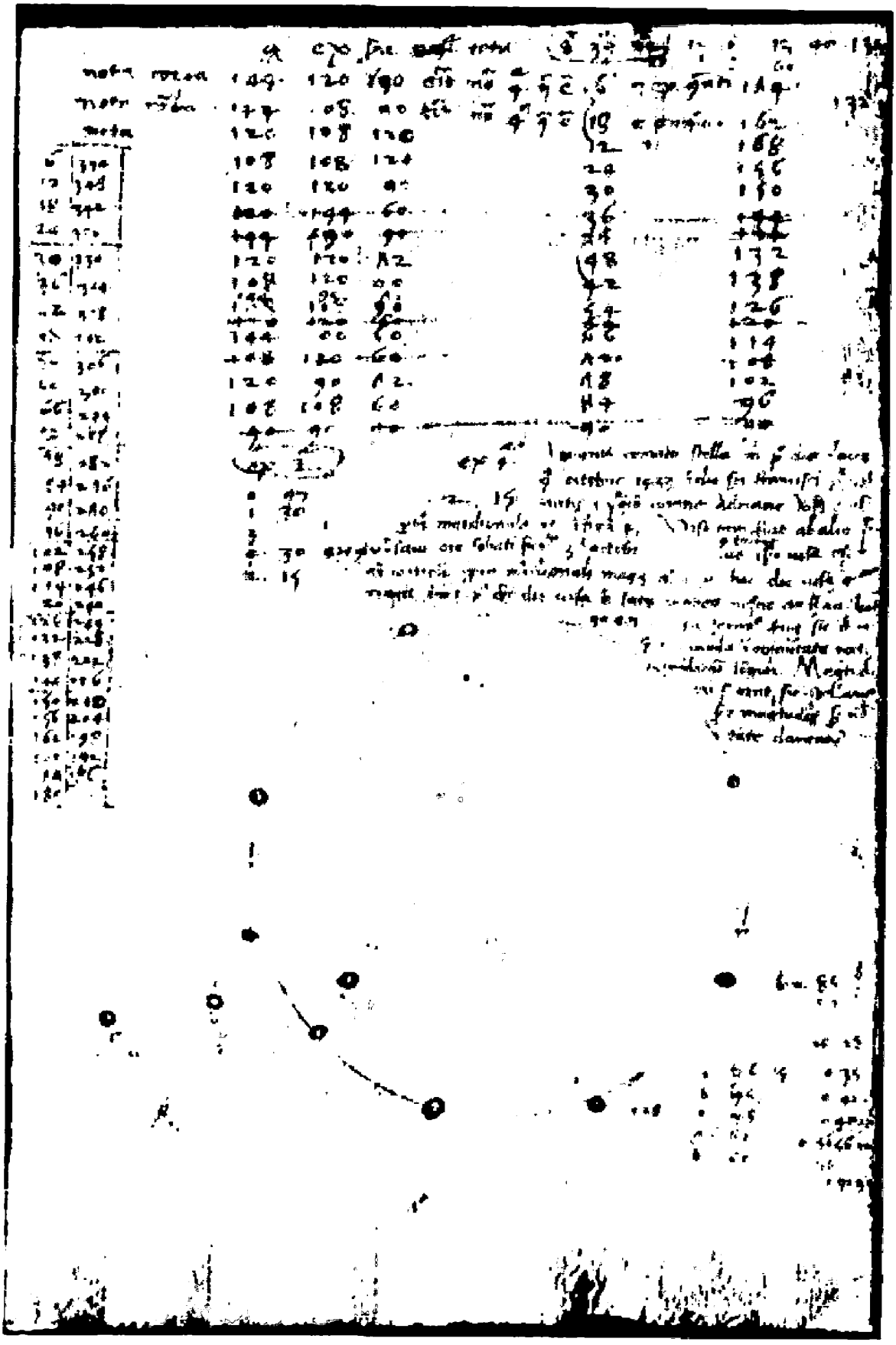
IV. Folio 235: Treatise fragment on comet of 1456.



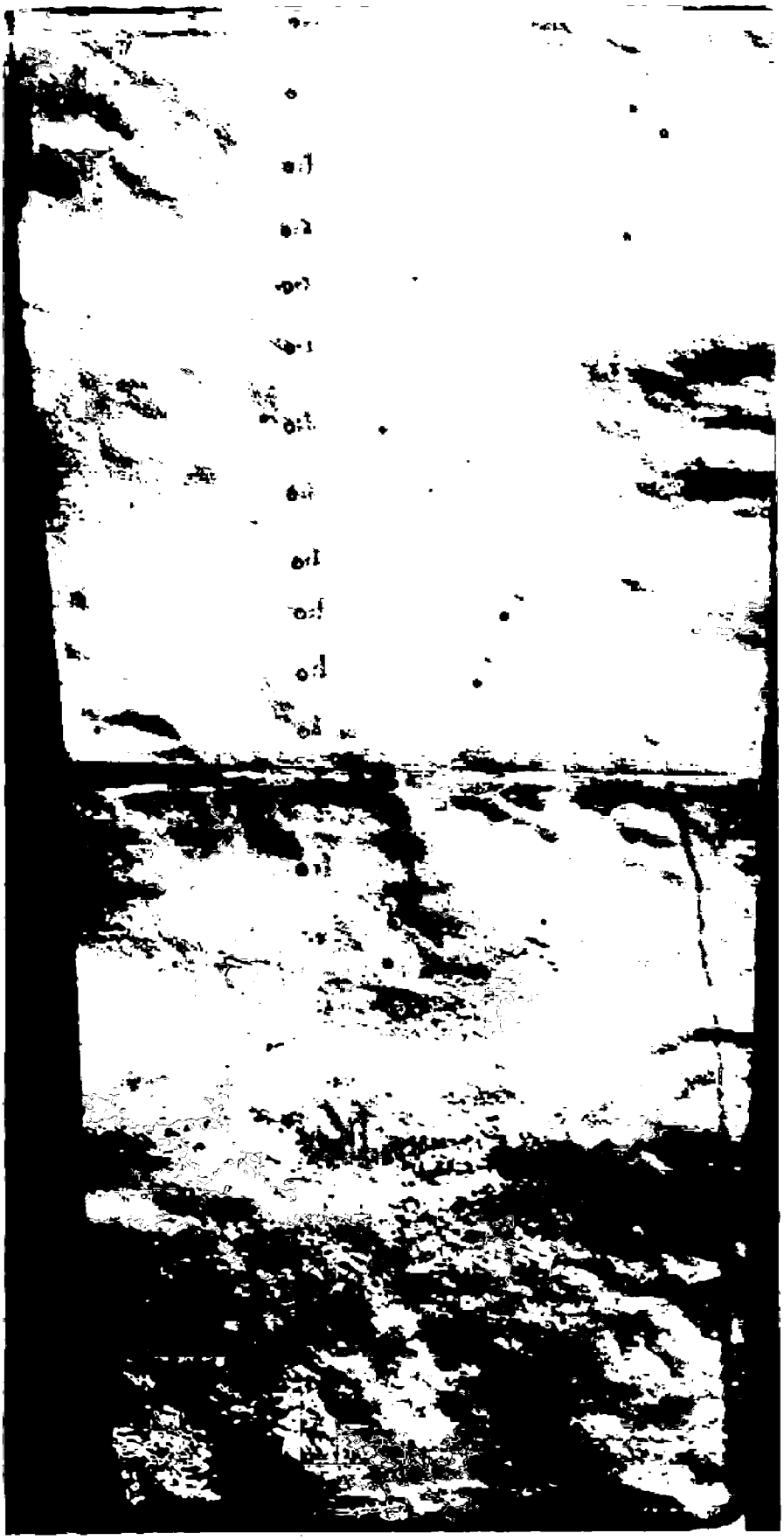
V. Folio 244: Ascription to Toscanelli.



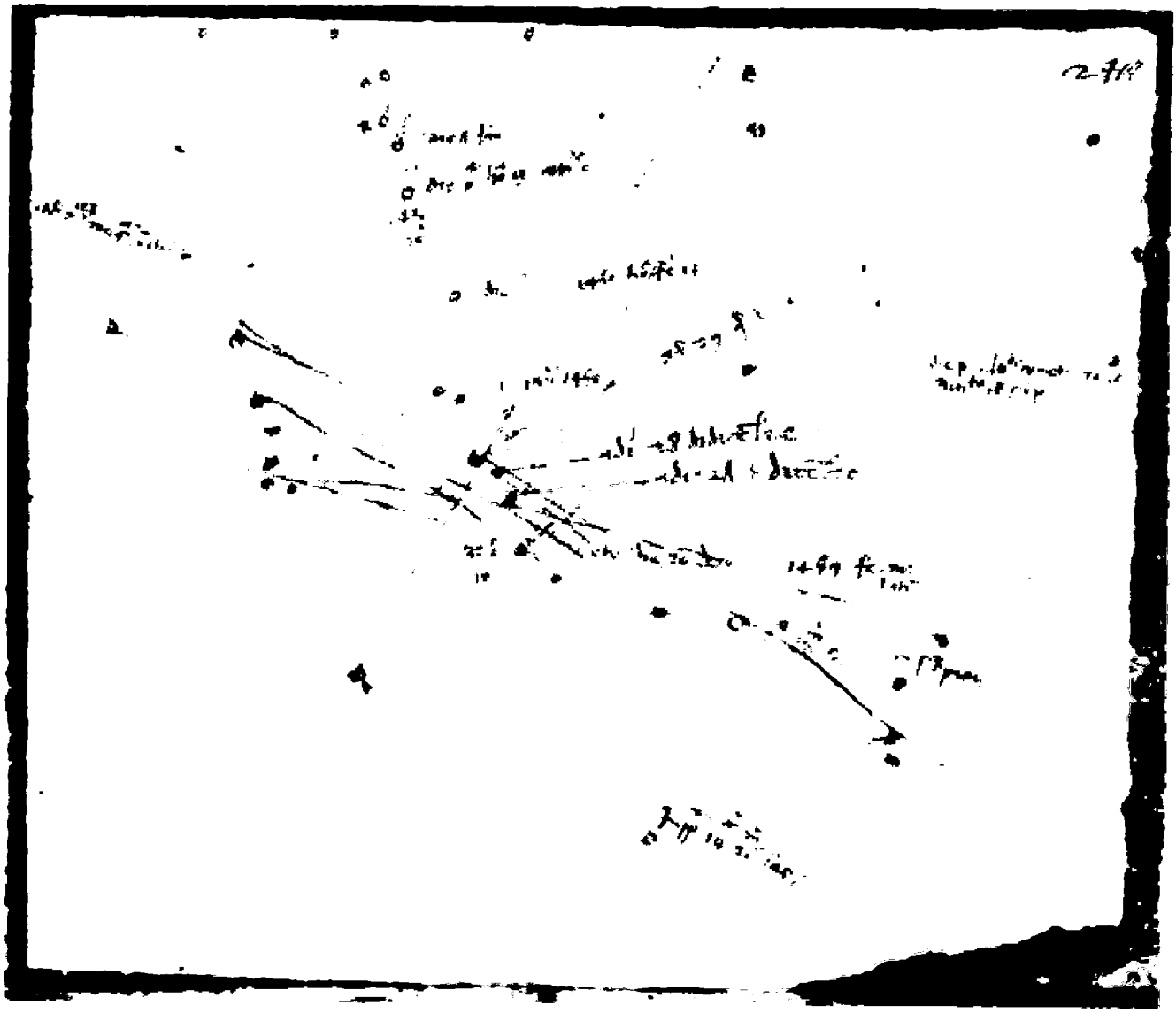
VI. Folio 245: Mathematical calculations.



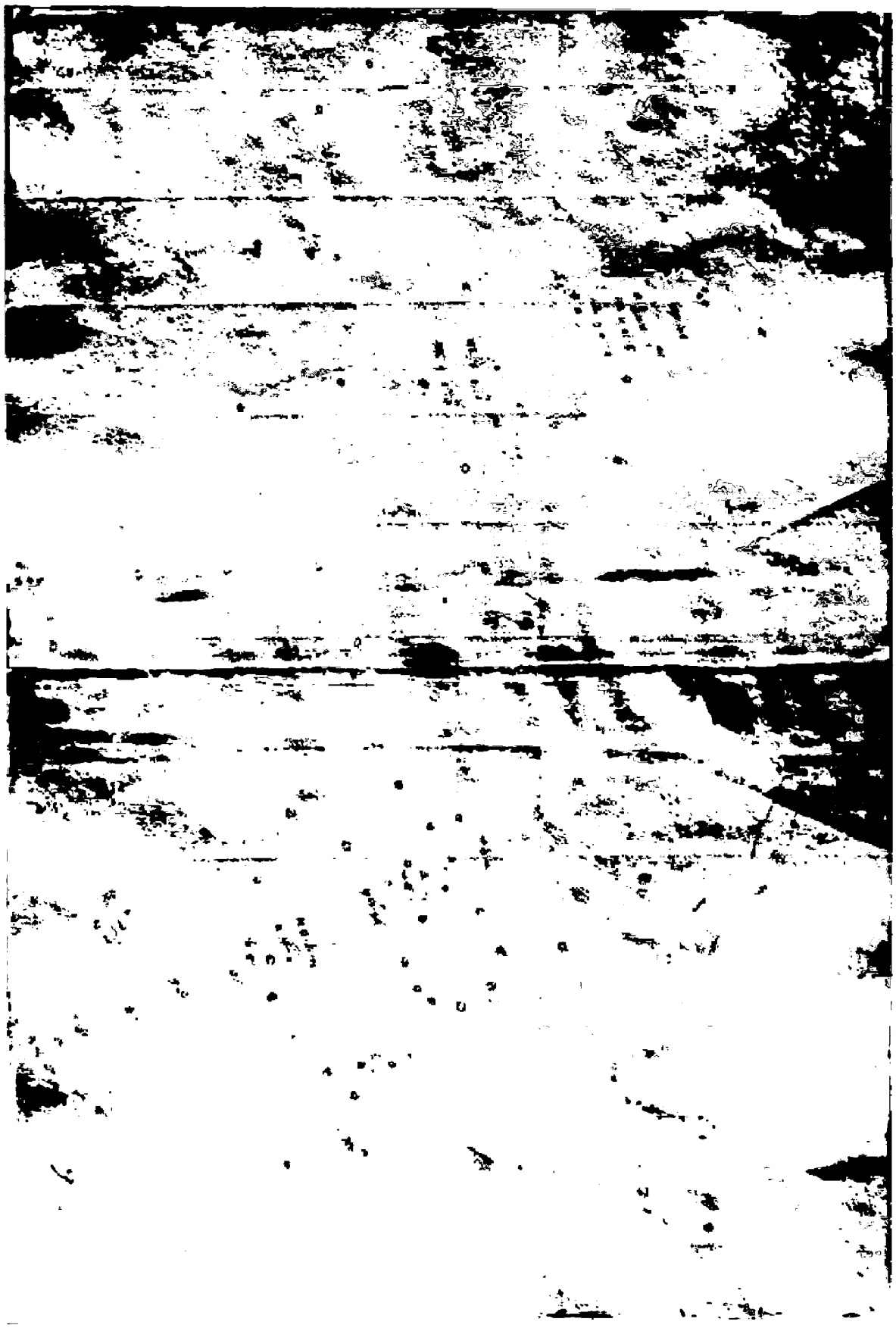
VII. Folio 245 v: Comet of 1433.



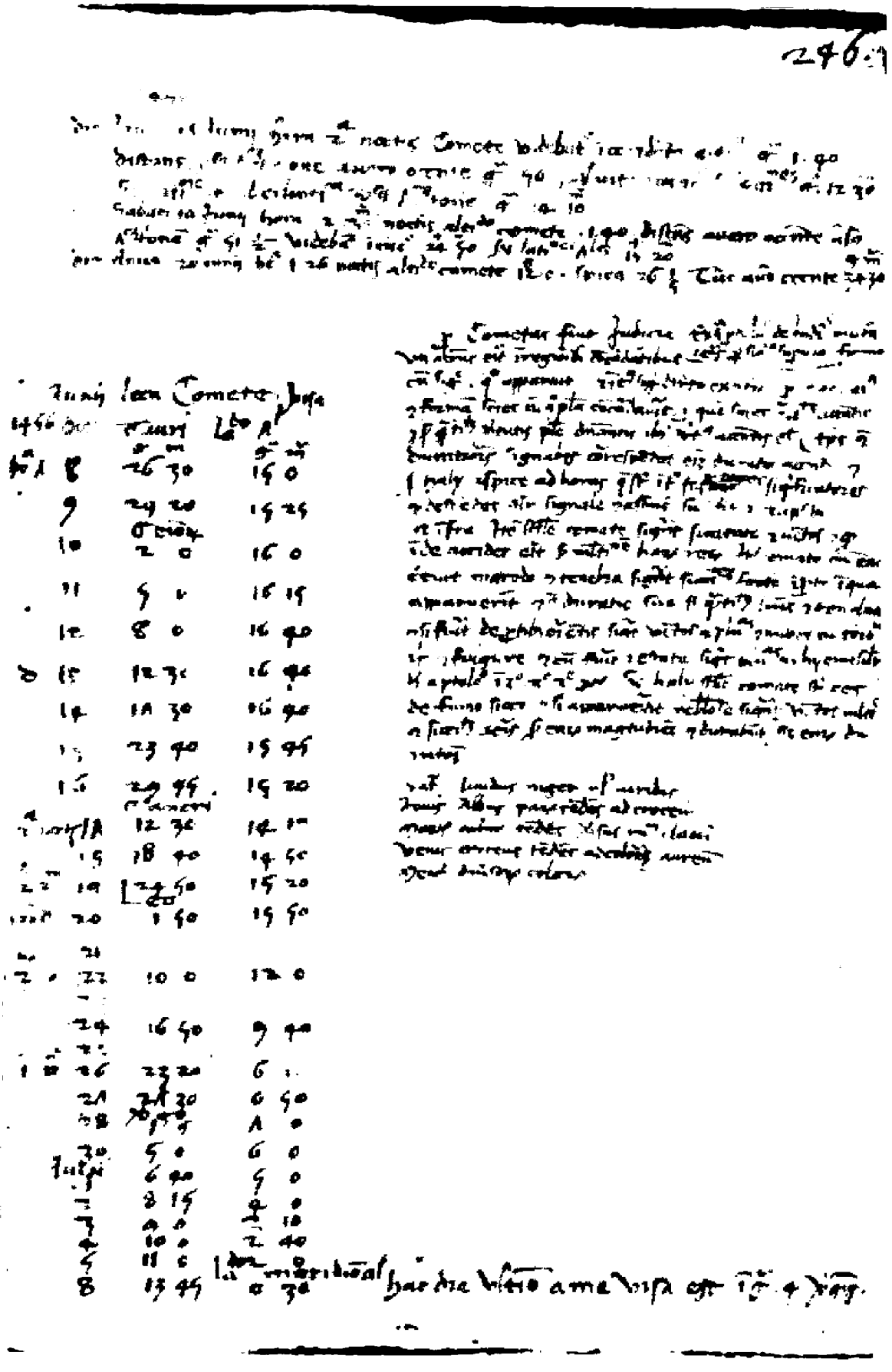
VIII. Folio 248 r: Comet of 1433.



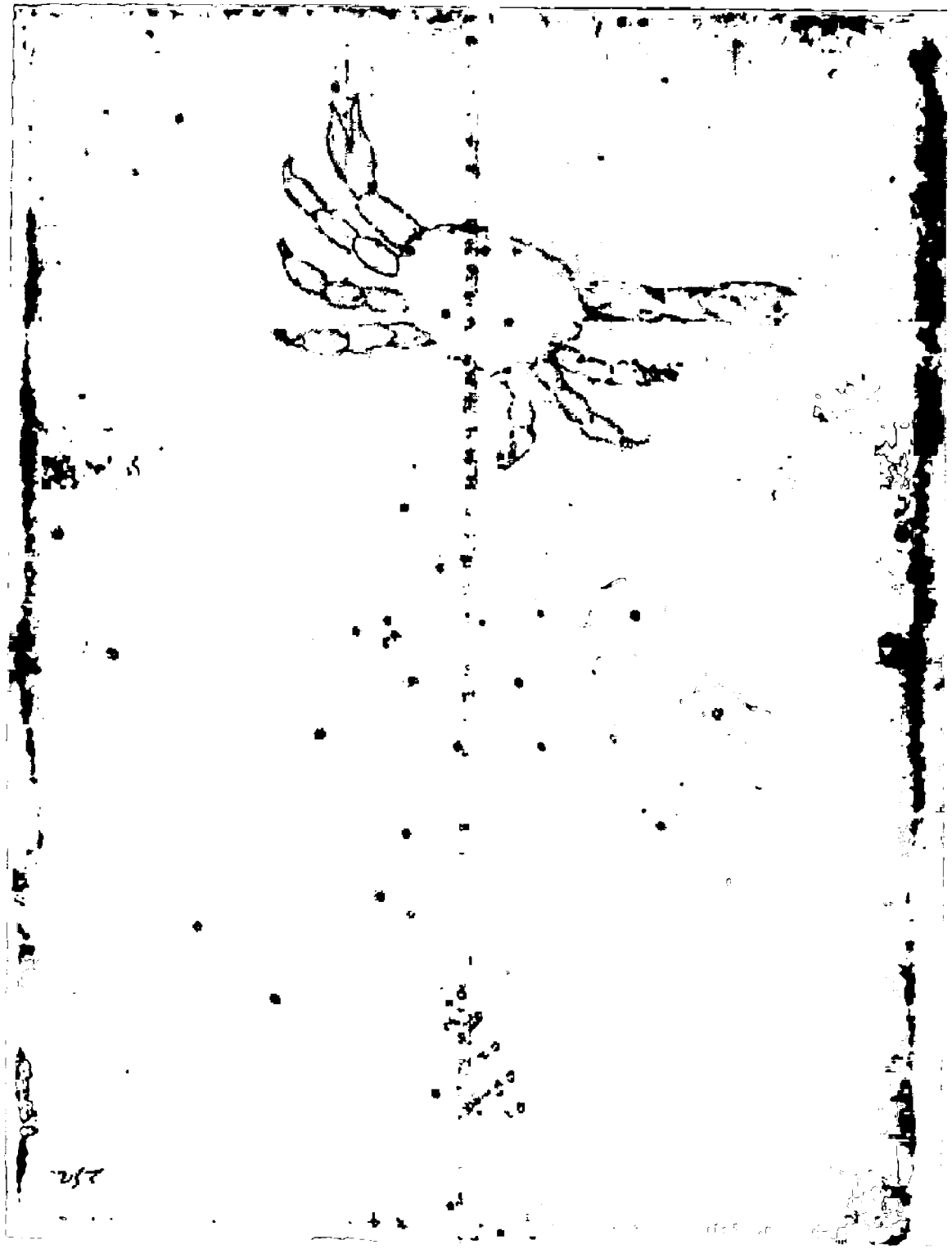
IX. Folio 242 r: Comet of 1449–1450.



X. Folio 250 r: Comet of 1449–1450.

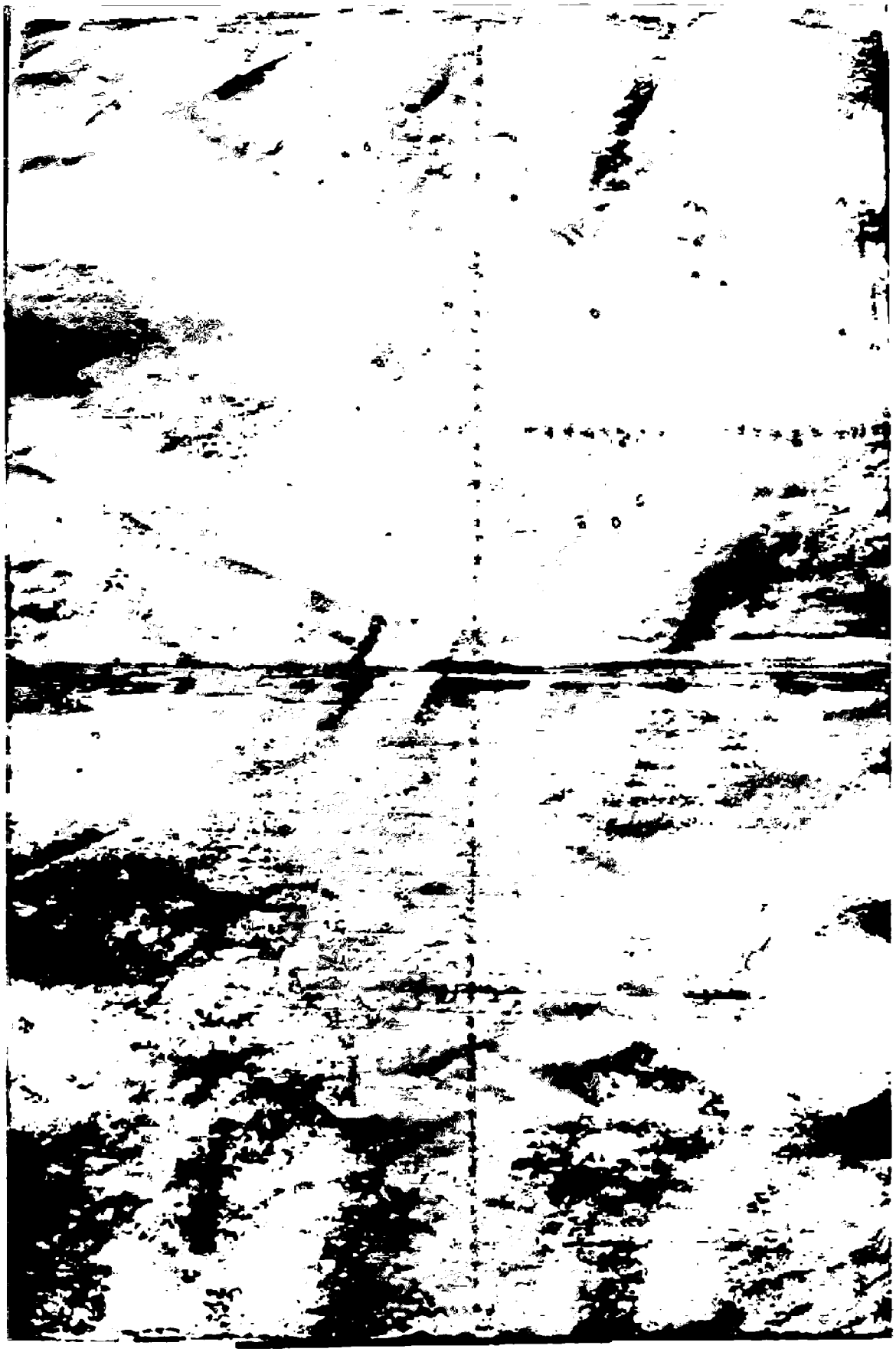


XI. Folio 246: Comet of 1456.

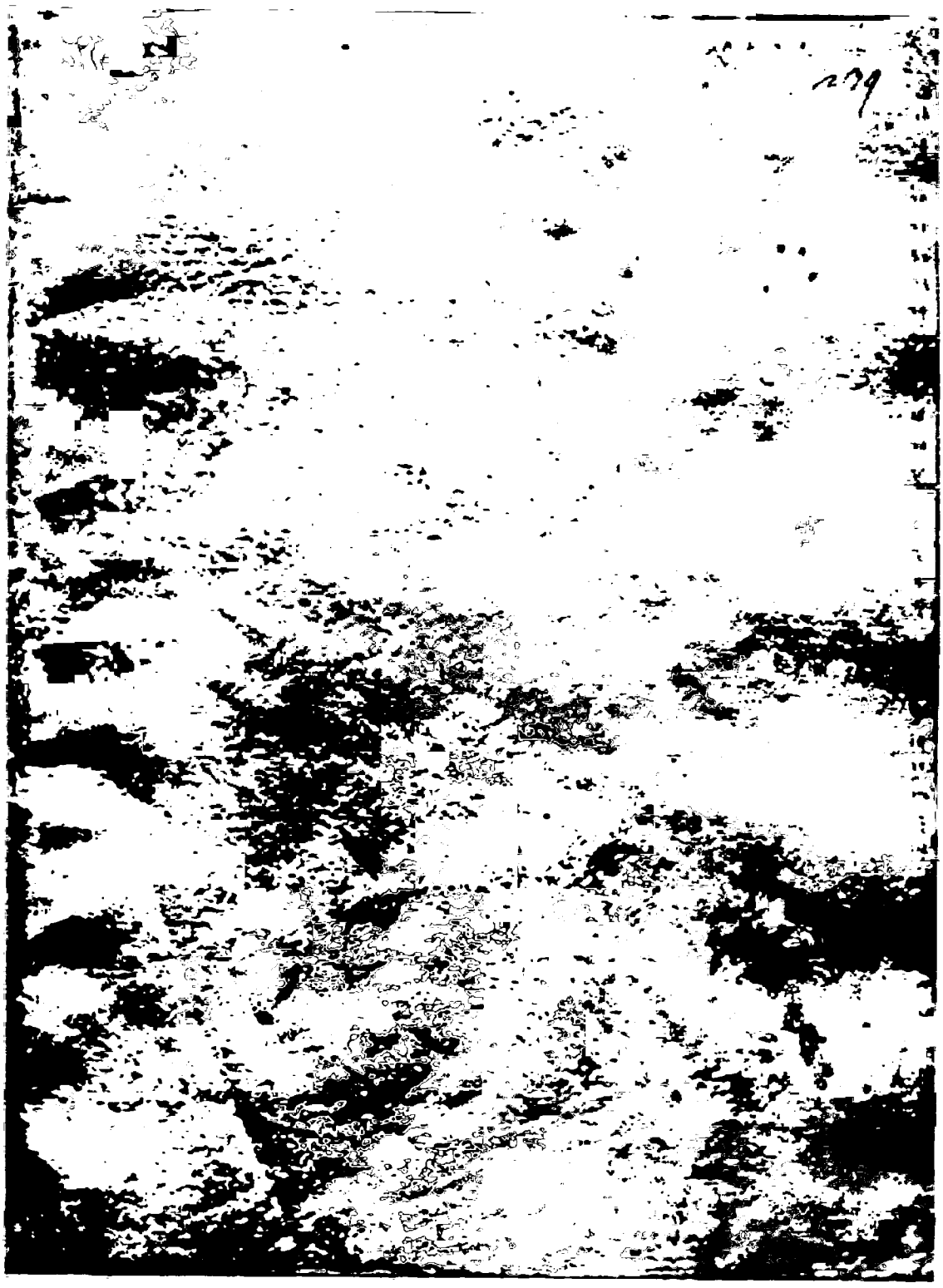


XII. Folio 252 r: Comets of 1456 and 1457-II

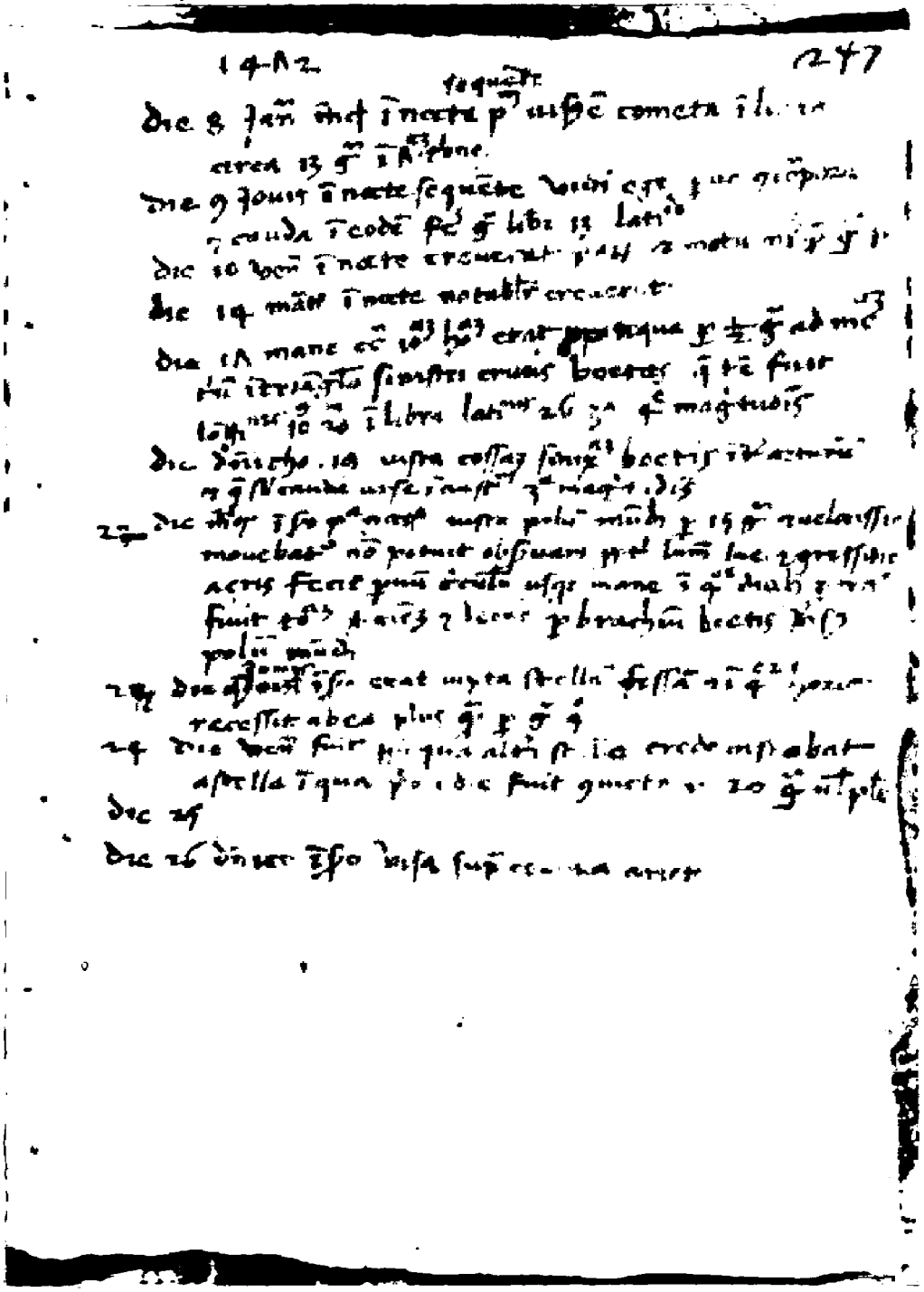
XIII. Folio 257 r: Comet of 1456.



XIV. Folio 240 r: Comets of 1457-I and 1457-II.



XV. Folio 239 r: Comet of 1457-II.



1472 247

Die 8 Jan̄ ad̄ i nocte p̄ ūsp̄ cometa i l...
circa 13 g̃ ♏ stone.

Die 9 Jouis i nocte sequēte uidi eē ⁊ ue ꝯpicuā
⁊ eadē i eodē pte g̃ libr 13 latūd

Die 10 ven̄ i nocte crescebat p̄ dū ⁊ motu ꝓp̄ g̃ ♏

Die 14 mārt i nocte notabiliter crescebat

Die 15 mane cū 10 hor̄ erat ꝓpinqua ♏ g̃ ad mē
dū i tertio signo boreas ⁊ tē fuit
longitudo 10 ♏ i libra latitudo 26 g̃ q̄ magnitudo

Die dñica 18 ultra ecliptā signū boreas ⁊ australe
⁊ g̃ secunda ursa ⁊ anser ⁊ magn̄ dis

22 Die ♄ ista q̄ nocte ultra polū mūdi ⁊ 15 g̃ nubes
nebule nō potuit discerni p̄ lūm luc ⁊ grossities
aeris fecit q̄ cito usq̄ mane i q̄ dam ⁊ mā
fuit tēs ⁊ aer ⁊ locus ꝓbrachiū beate ♈
polū mūdi

24 Die ♃ ista erat mota stella ꝓpe ♏ i q̄ ⁊ ꝓxime
recessit abeā plus q̄ ♏ ⁊ g̃ ♎

24 Die ven̄ fuit p̄ q̄ dā alti ⁊ ita crebe mō abat
stella i q̄ ⁊ ꝓ eā die fuit q̄ ⁊ 20 g̃ ut ꝓ

Die 25

Die 26 dñica ista ꝓpe ...

XVI. Folio 247: Comet of 1472

VI. GEORG PEURBACH

Not very much is known about Peurbach's life and there is very little modern scholarly work focused on him. Gassendi wrote his biography but it is disappointingly low in content; he did not, for example, mention Peurbach's work on comets (Gassendi 1658: 519–534). Peurbach and Regiomontanus together were hailed in the sixteenth century as the restorers of astronomy after more than a millenium of neglect. Thorndike thinks they were overrated (indeed, he thinks little of the scientific work of the fifteenth century as a whole) and devotes a chapter of his *History of Magic and Experimental Science* (V: chap. 16) and another in his *Science and Thought in the Fifteenth Century* (1929: chap. 8) to collecting these sixteenth-century encomia and to demolishing them. He attributes their fame to the wish, common in the renaissance, to denigrate the accomplishments of the recent past and to glorify excessively the restoration and the restorers of classical learning. There is some truth in this, but Thorndike goes too far. Both Peurbach and Regiomontanus seem to have made solid contributions of their own.

Peurbach was born at 3: 05 p.m. on May 30, 1423, according to his horoscope, and first enrolled at the University of Vienna for the summer term in 1446, receiving his baccalaureate in 1448 and becoming master of arts there in February 1453 (Zinner 1968: 27). Some time before 1453 he had travelled to Italy where he met Giovanni Bianchini and Nicholas of Cusa. At Vienna he was strongly influenced by Aeneas Silvius Piccolomini, papal legate to Austria and later Pope Pius II (1458–1464), who was an enthusiastic humanist and who lectured widely on the value of classical scholarship. Peurbach was an admired Latin stylist and lectured at the University on Juvenal in 1456, Horace in 1458, and Virgil in 1460 (Cantor 1892: 165). He wrote a number of lyrical love poems in Latin, all of them addressed to men, a fact which Zinner found distasteful and surprising (Zinner 1968: 28).

During the 1450s Peurbach occupied the chair of astronomy established at the University of Vienna for John of Gmunden. It is not clear whether the two ever met; Peurbach was nineteen when Gmunden died, but his matriculation at the University was not until four years later, and Gmunden had been retired for some time before his death. Peurbach wrote a theory of the planets which was published fourteen times between 1460 and 1581 (Cantor

1892: 166). He wrote a theory of eclipses which also went through many editions, and an arithmetic which was a standard university text well into the sixteenth century (Janssen I: 472). He composed a number of tables of sines and chords, invented a quadratum geometricum (described and illustrated by Cantor 1892: 169), constructed sundials, wrote planetary ephemerides, and made observations of stellar and planetary positions.

Much of the evidence for Peurbach's work is found in his correspondence with Johannes Bohemus, or Johannes Nihil, published by Czerny (1888: 281 –304). Johannes was chief astronomer to Emperor Frederick III, and the two men seem to have been friends as well as scientific colleagues. In 1460 Cardinal Bessarion commissioned Peurbach to write a commentary on Ptolemy's *Almagest* but his death the following year interrupted that work, the *Epitome of the Almagest*, which was completed by Regiomontanus. Peurbach was about to go to Italy with Bessarion to study Greek when he died; his place in Bessarion's entourage was taken by Regiomontanus.

Peurbach's work on comets appears in two places: in a letter to Johannes Bohemus and in a treatise on the comet of 1456, later identified as Halley's comet. These will be discussed in turn.

LETTER: 25 JUNE 1456

This letter is part of Peurbach's correspondence with Johannes Bohemus published by Czerny in 1888. Czerny states that this letter was one of two in the collection in Peurbach's own handwriting, but in the Xerox copy I have from the Stiftsbibliothek Wilhering, codex 105, cited by Czerny, it appears to be in the same hand as the rest of the manuscript and is not on a separate page; it looks like a scribal hand to me. Czerny does not say on what basis he believed it to be an autograph copy; from the manuscript copy I have seen, I must disagree with him. My translation is as follows:

Vienna-Neustadt, 25 June 1456

Most illustrious man and dearest brother. I have been able to write you rarely these days, being sometimes surpassingly impeded, sometimes overwhelmed by a multitude of things. A comet has appeared, some say two appeared, some say four, which I did not yet see [*quos ego nondum vidi*]; but it is my opinion that that which in days past appeared before the sun now began to appear after sunset, following the sun. Many have asked me to predict the significance of these; to them I am accustomed to answer in the manner of a statue. In general, however, the answer is: In past years such bearded stars have appeared; you all have seen the results of these, and, if you are not expert enough, you should make inquiry of others. People pester me with questions if I do not get rid of them by these and other answers.

I wrote to Master Johannes Schindel [an astronomer in Prague]: In 1402 around the beginning of February, a great and horrible comet appeared in the sign of Aries; its declination was 18 toward the north and it lasted more than through the middle [of February?]. First appearing very much toward the north, it was seen to decline and later set in the sign of Libra – – certainly I acknowledge [this behavior?] to be very much characteristic of itself. Also in 1433 a white comet appeared, not visible for very long, in Gemini. Its latitude to the north was almost 35°. In the same month it approached the sun and disappeared. I belivele that it was thus. I beg you to inform me of your position and approach.

The letter continues, but there is no more about comets in it. The observational data are vague, and it is difficult to know what he meant when he said he had not yet seen them; I suppose he meant that he did not see four comets but did see the one, both in the evening and in the morning (see the treatise below). There is no indication of what he believed comets to be, or where, though there is some indication of his astrological scepticism.

TREATISE: COMET OF 1456

There are several extant versions of Peurbach's judgement on the comet of 1456. They have been discussed and partially published by Lhotsky and Ferrari d'Ochieppo (1960) and by Ferrari d'Ochieppo (1960) alone. We have a rather brief German treatise, written while the comet was still visible, then a longer and more formal Latin treatise, written after the comet had disappeared, and several copies and extracts of the longer work. Although Peurbach is explicitly identified as the author in only one of these versions, and this not the earliest one, there is no doubt in my mind that these are all versions of the same work because of similarities of material covered, organization, and style, even though there are two languages involved. There does not seem to be any reason to challenge the attribution to Peurbach.

1. The German treatise: Vienna Staatsbibliothek ms. 4756, folios 139 r – 140 v, begins "Gnedigster Herr. Ytz ettlich tage..." It is discussed by Ferrari d'Ochieppo (1960: 150–154, text on 163–165). This treatise was apparently hastily written at the insistence of the "gnedigster Herr", probably Ladislaus V of Hungary whose court astrologer he was, around 20 June 1456, when the comet was at the beginning of Leo. This manuscript is a copy written around the start of the 16th century. It is divided in five parts: on the comet's course, its origins, its size, its nature, and its significance. There are two observations given, for June 9 and 13, and the place of first appearance is computed back by linear extrapolation. There is no discussion of cometary distance in this version.

2. The Latin treatise: Stiftsbibliothek der Abtei U. L. Frau zu den Schotten, Vienna, ms. 312 (formerly 405), folios 109–118 (Zinner 1925: # 6149). It is discussed by Ferrari d'Ochieppo (1960: 149–150, 157–158); he believes that this is the earliest of the extant Latin versions, written at the abbey shortly after its composition. It is virtually identical with the two copies at the Vienna Staatsbibliothek and at St. Pölten. The author is not identified.

3. The Latin treatise: Vienna Saatsbibliothek ms. 4756, folios 20 r – 25 r, the same codex which contains the German treatise. (Zinner 1925: # 6150.) Ferrari d'Ochieppo concludes from analysis of the handwriting and scribal errors that it is intermediate in age between the Schotten manuscript and the St. Pölten manuscript. The author is not identified; the treatise has been identified as "attributed to Peurbach" (Hellman 1944: 73; Thorndike 1958:

226; Zinner 1968: 36). This is the version of the treatise which I used for translation and analysis.

4. The Latin treatise: St. Pölten Alumnatsbibliothek (manuscript number not given) folios 143 r – 149 v. Referred to by Zinner (1968: 36) as ms. XIXa; not listed in Zinner (1925). Discussed and text given by Lhotsky and Ferrari d'Ochieppo (1960). It is in this copy that the author is identified explicitly as Peurbach. It was written around 1500.

5. The Latin treatise: Melk Stiftsbibliothek, ms. 59, folios 162 r, v (Zinner 1925: # 6151). This is discussed by Ferrari d'Ochieppo (1960: 156 – 157; text on 166 – 167). It is a shorter version with whole sentences excerpted verbatim by an intelligent excerpter. The author is identified in the title only as "magister studii wiennensis, sublimis astronomus", but all the chapters except the first begin with the words "Peurbacher dicit..." Ferrari d'Ochieppo believes from internal evidence that this excerpt was made from the Schotten manuscript, n° 2 above.

6. The Latin treatise: a synopsis by the chronicler Thomas Ebendorfer von Haselbach. Manuscript source not given; partial text given by Ferrari d'Ochieppo (1960: 167 – 168). It seems clear that this also is a synopsis of the Peurbach treatise, though not so literal as the preceding one, not an original work by Ebendorfer. Peurbach is not mentioned.

My translation of the Latin treatise was made from a Xerox copy of the Vienna ms. 4756, n° 3 above, before I had access to the transcription by Lhotsky and Ferrari d'Ochieppo (1960: 271 – 276) of the St. Pölten manuscript, n° 4 above. I have found no differences between the two which affect the meaning. Because the text has been published recently, I will not repeat the Latin, but will summarize the text, giving my translation of the passages containing observational data.

Judgement on the comet which appeared in 1456 A.D. for almost the entire month of June; written at the bountiful university of Vienna.

The author opens with a justification for writing, to quiet the fears of the ignorant.

[fol. 20 r]... Therefore it is sensible to write something of the comet which was seen in our time, 1456 A.D. First it is necessary to speak of the time and part of the sky in which it appeared to arise and move, and of its motion.

The night following the ninth of June, at a quarter past midnight, I saw a comet rising above the horizon at Vienna. Its head appeared next to the star which is in the right foot of Perseus; the tail extended against the succession of the signs toward the head of Algol all the way to the star which is in the buttock of Perseus. So its head was in Gemini 6°, latitude 19°, and the tip of the tail was in Taurus 26°, latitude 22° toward the north, the values determined [*deprehendi*] by instruments. So from head to tail it was 10° in length. It moved by the motion of the celestial sphere preserving its place relative to the fixed stars mentioned above. And with them it was seen ascending to the zenith until the third hour past midnight when the brightness of dawn hid the light of the stars.

[fol. 20 v] It was seen the night following June 3, six days before I saw it. In order to find its true relations I began noting continuously its rising and position and found them changing.

Thus on the night following June 13, its head was in Gemini 22° with latitude 16°, from which it is evident that the proper motion of this comet in four natural days was 16° of longitude according to the succession of the signs and 3° of latitude. Whereby assuming uniform motion in the said time, at its first appearance the head would have been in Taurus 12°, latitude 24°, with the tip of the tail in Taurus 2°, latitude 27°. It appeared through about a lunar month during which by its own proper motion it hastened from about the beginning of Taurus to the beginning of Virgo. At first it rose in the morning before the sun, then in the evening after sunset; hence it was that those who are ignorant of celestial motion thought that they saw two comets, considering it to be impossible that in one and the same day the same star should appear to us both in the morning before sunrise and in the evening after sunset; this was because of its northern latitude. [cf. letter above] Thus from this it is concluded that this comet had a triple motion. The first follows the daily motion making about one revolution in a natural day with the stars next to which it appears. Next it moved by its own motion according to the succession of the zodiac in such a way that, in the lunar month in which it appeared, it progressed through four signs dragging its tail behind it. Third, it changed latitude from the ecliptic in the course of its own proper motion. Thus from the beginning of its appearance it approached the ecliptic [fol. 21 r] until it had come to the middle of Gemini, from whence into the middle of Cancer it held the same latitude. But afterwards, toward the end of its appearance its latitude decreased until it was near the equinoctial circle, where it was seen to move parallel to it. The first of these motions it took from that region either of fire or of highest air in which it was constituted, in which it participates not by violence but by natural obedience with certain properties of the celestial spheres of sphericity, uniformity, perfection, and transparency, as Aristotle said in his *Meteorology*. The circular motion of the *primum mobilis* is followed. But it has other motions which are its own, not indeed as some claim by retardation from it, as that highest part of the elements cannot keep up with the speed of revolution of the prime mover because of its remoteness from it, for this retardation cannot suffice to explain the proper motion of comets. In one case a comet was seen to have moved from Cancer 8° retrograde in the ecliptic into the end of Gemini, and another was seen to procede from north to south through more than 50° in latitude, but according to longitude scarcely 5°. Therefore it has its own motion by virtue of the planet which generates and rules it. And so enough is said of its motion and location.

The next section discusses the material and efficient causes of comets, basically according to Aristotle. Hot dry exhalations rise to the upper regions of the air or the region of fire and are ignited under the influence of the stars and planets, especially Mars and Saturn. Then Peurbach describes the nine types of comets; he says that these types were distinguished by Ptolemy according to color and shape. He goes on to discuss the distance of this comet from the earth, with a brief digression on those who disclose their ignorance whenever they speak.

[fol. 22 v] But let us return to the main point. By very secure demonstration Ptolemy, that most clever man, in the *Almagest* concluded that the radius of the sphere of elements is 33 times the earth's radius. Moreover, [fol. 23 r] experience teaches that 16 German miles are subtended by one degree of a great circle in the heavens. To investigate further by the ratio of the diameter and circumference, as Archimedes showed us, it is clear that the earth's radius contains about 1000 miles, and from the earth to the inner surface of the moon's sphere is about 30,000 of these miles. But no one of sound mind has ascribed a thickness to the region of fire of 27,000 German miles. It follows, therefore, since the comet stands in the highest air below the region of fire, that it is distant by more than a thousand German miles, which is well enough affirmed from the appearance of the parallax. In the comet which was brought forth this year, now seen both in the morning and in the evening, its appearance [the parallax] showed little variation in three

hours with respect to the horizon [*in tribus horis fere respectu orizontis paulo variata fuit*] determined in any way you wish. From its distance from earth and the 10° angle which the comet's length was seen to subtend and from the proportions, I concluded that the comet's length was more than 80 miles [*sic*] and its thickness more than 4 miles.

There follows a brief discussion of the quantity of matter necessary to sustain a fire of this size, and then a rather lengthy discussion of the portents of the comet.

The positional data are analyzed by Ferrari d'Ochieppo, compared (favorably) with Toscanelli's observations and with modern information on the orbit of Halley's comet (Lhotsky and Ferrari d'Ochieppo 1960: 277 – 290). I would like to point out here only the mention of observational instruments, unspecified, and the general impression of firm control of the data. Unfortunately there are only two positions given, for June 9 and 13; we do not have here an orderly sustained series of observations like those in Toscanelli's manuscript. It would be interesting, of course, to have Peurbach's primary data instead of, or addition to, this well digested presentation.

Peurbach's argument on cometary distance is as follows. We know the dimensions of the sublunar sphere from Ptolemy: its radius is 33 times the earth's radius. We know that 1° on the celestial sphere subtends a distance of 16 German miles on the surface of the earth, so 1° of circumference on the earth is equal to 16 German miles. The total circumference of the earth is thus $360° \times 16 = 5760$ German miles, and the radius is this quantity divided by 2π or, very roughly, 1000 German miles. Note that he rounds off his numbers very generously; he is only estimating. Then, he continues, the radius of the sublunar sphere is 33,000 German miles, so the distance from the earth's surface to the inner surface of the moon's sphere is $33{,}000 - 1{,}000 = 30{,}000$, very approximately. The question is whether comets are in that interval. He accepts as true the Aristotelian assertion that they are in the upper region of air, below the sphere of fire. Then, he says, because it is unreasonable to suppose that the sphere of fire is as thick as, say, 27,000 miles, the comet must have been more than a thousand miles away. (I do not know why he chose 27,000.) The suggestion here is that it is probably much farther than that and that he is arguing against someone or some tradition that placed it much closer. One of the questions perhaps tacitly being considered is how thick the atmosphere is; if we know that comets are formed at or near the interface between air and fire and we can determine their distance by parallax measurements, we would then know the thickness of the sphere of air. That the parallax "showed little variation in three hours" then is taken as proof that the comet is at least this far away.

The length Peurbach derives for the comet of more than 80 German miles based on a distance from earth of more than 1000 miles and a subtended arc of 10° is wrong by a factor of 2; it should be more than 160 miles. The same numbers are given in the German treatise. Ferrari

d'Ochieppo (1960: 154) proposes that the error was made in haste in the early text, that having realized it Peurbach did not correct it in the later text because he did not want to admit error, thinking that no one would notice it, and that the uncritical acceptance of the numbers in later copies of the treatise proved him right in his cynical assessment of his readers. (Even Zinner ⟨1968: 37⟩ accepts the 80 miles without comment.) This seems to me to be an unwarranted interpretation; far more likely that Peurbach himself uncritically accepted his preliminary result. From the context it appears that Peurbach's interest in the actual size of the comet was motivated by a wish to estimate the quantity of exhalations involved.

The most important portion of this treatise for our purposes is Peurbach's inclusion of parallax in his discussion of the comet's distance from earth. This is the first time that I know of that an attempt was made to measure (or estimate) parallax for comets, and I believe that it was this attempt which Regiomontanus picked up and elaborated on in the *Sixteen Problems* (see chap. VII below). It should be noted here that the effect which they were trying to detect and measure was a rather large effect — — they expected to find a daily parallax of several degrees, significantly larger than the parallax of the moon.

VII. JOHANNES REGIOMONTANUS

The facts of Regiomontanus' life are fairly well documented (Zinner 1968; Rosen 1975; Rose 1976). Most recent work on him derives from Zinner's exhaustive studies, which are excellent though occasionally marred by German chauvinism. Regiomontanus was born Johannes Mueller in Königsberg, Bavaria, on June 6, 1436. He went to study at Leipzig when he was twelve, then enrolled at the University of Vienna in 1450 and studied mathematics and astronomy with Peurbach, who occupied the chair of astronomy established for John of Gmunden earlier in the century. Although he received his bachelor's degree in 1452 at the age of 15, university regulations prohibited granting him the master's degree until he was 21. He remained at Vienna, however, as student and collaborator of Peurbach, and was appointed to the faculty in 1457 (having reached his majority and presumably received the M.A.).

In 1460 Cardinal Bessarion (1403–1472) came to Vienna as papal legate and encouraged Peurbach to undertake a condensation and explication of Gerard of Cremona's twelfth-century translation of the *Almagest*. Peurbach died in 1461 before completing this *Epitome of the Almagest*, and Regiomontanus took over the job, finishing it some time before 1463, though it was not printed until 1496. Regiomontanus had in the meantime begun to study Greek, probably with Bessarion whose native tongue it was. In November 1461 Regiomontanus left Vienna for Rome with Bessarion and in July 1463 they both went to Venice. In the spring of 1464 Regiomontanus gave a series of lectures at the University of Padua on al-Farghani; only the introductory lecture survives, in which he expounded the value of mathematics and the importance of accurate translation and exposition of ancient texts (Rose 1976: 95–98). He had probably by this time completed his book, *De triangulis*, but it was not published until 1533.

In a long letter to Giovanni Bianchini early in 1464, Regiomontanus refers to a determination of the obliquity of the ecliptic of approximately 23°30′ made by Toscanelli and Alberti (Murr 1786: 148). And it was in June and July of 1464 at Venice, that Regiomontanus wrote his rebuttal to Nicholas of Cusa's treatise on the quadrature of the circle, addressing it to Toscanelli: Cusa's treatise and Regiomontanus' reply were published as an

appendix to the book on triangles in 1533 (text in Schmeidler 1972: 417 – 510). We may conclude then that it was some time between late 1461 and early 1464 that Regiomontanus and Toscanelli became acquainted, if at all. There is no evidence that they met that I know of.

In August 1464 Regiomontanus and Bessarion returned to Rome for the election of a new pope, and in Rome Regiomontanus wrote his attack on the planetary theory of Gerard of Cremona, usually referred to as *Contra Cremonensis*. There are a couple of years of Regiomontanus' life unaccounted for, but in 1467 he was at the court of Mathias Corvinus of Hungary, where the court astronomer was Martin Bylica of Olkusz (1433 – 1493) whom he had known in Italy and with whom he was to collaborate on several astronomical and mathematical tables. Martin designed a set of astronomical instruments including a celestial globe, a torquetum, and an astrolabe which are preserved in the collection of the Jagiellonian University in Cracow (Zakrzewska 1965: 7 – 8; Ameisenowa 1959).

Hungary was at war with Bohemia and in 1471 Regiomontanus found it prudent to leave. He chose to go to Nuremberg, attracted by the city's excellence in crafts which would enable him to procure astronomical instruments, and by the presence there of a printing press (Curtze 1902: 329; Rose 1976: 103 – 104). He became friends with Bernhard Walther, a wealthy patron of scholars and a scholar and astronomer in his own right. Walther's patronage enabled Regiomontanus to have numerous instruments made and to establish an observatory (Pedersen 1976: 17). In addition Regiomontanus directed a printing establishment especially for works in mathematics and astronomy, both ancient and contemporary, including of course his own. One of his first publications was a catalog of books he intended to publish.

In 1475 Pope Sixtus IV summoned him to Rome to work on the reform of the calendar; he went reluctantly at the urging of Bessarion and died within the year. His death was variously attributed to poisoning, to the plague, and to a comet, and he was publicly mourned in Nuremberg.

The story of Regiomontanus' estate is dramatic and complicated, full of intrigue and deception. Zinner (1968: 245 – 266) devotes an entire chapter to it. The printing establishment was apparently closed and the equipment sold after Regiomontanus' death; his books and instruments were bought by Walther who used the instruments to continue the observations they had been working on together (Beaver 1970: 39), and sequestered the books and papers, allowing no one access to them. After Walther's death in 1504, his executors allowed them to be used (this is when Ziegler copied down the treatise on the comet of 1472), but apparently started selling the books piecemeal, denying the while that they were doing so. There was much excited correspondence and several lawsuits as rulers and scholars squabbled over the remains. Some time before 1522 most of the remaining books were bought by Wilibald Pirkheimer. He later sold many of them to Johannes Schöner, who published some of Regiomontanus' works in the 1530s and

1540s before his death in 1547. These circumstances account for the very long interval between publication of most of Regiomontanus' works.

Three documents relating to comets were published in the mid sixteenth century under Regiomontanus' name: 1) *Sixteen Problems on the Magnitude, Longitude, and True Location of Comets* was edited by Schöner and published in 1531 and again in 1544. This must be the work on the distance, size, and true place of comets referred to in Regiomontanus' publication catalog but never published in his lifetime (Zinner 1968: 179). 2) A single observation of the comet of 1472 made on January 20 of that year was published in a series of miscellaneous astronomical observations by Regiomontanus, Peurbach, and Walther in Schöner's *Scripta clarissimi*... of 1544 (the vast majority of the observations are by Walther, after 1475). 3) And a brief treatise entitled *De cometis* (of 1472) was published by Ziegler in 1548 and several times later in the sixteenth and seventeenth centuries.

I will present these three works in turn, in translation with my commentary. The original Latin of the longer works is given in the Appendix. I do not believe that the third work was written by Regiomontanus and will discuss the reasons for this as well.

SIXTEEN PROBLEMS

The first edition of *Ioannis de Monteregio Germani, viri undecunque doctissimi, de cometae magnitudine, longitudineque ac de loco eius vero, problemata XVI* which I shall refer to as the *Sixteen Problems*, edited and with a foreword by Johannes Schöner, was published in Nuremberg by Fridericum Peypus, 1531. A facsimile is given in Appendix C. The second edition is in a longer book titled *Scripta clarissimi mathematici M. Ioannis Regiomontani, de torqueto, astrolabio armillari, Regula magna Ptolemaica, baculoque astronomico, & observationibus cometarum, aucta necessarius Ioannis Schoneri Carolostadij additionibus*, Nuremberg by J. Montanus and U. Neuber, 1544. The *Sixteen Problems* occupies folios 79 r–88 r. It is not mentioned on the title page of the book, which has led to some confusion among historians and bibliographers. Ziegler lists this edition in his 1874 biography of Regiomontanus, but Zinner, Thorndike, and Hellman agree that Ziegler was mistaken and that the *Sixteen Problems* is not in this book (Hellman 1944: 81); evidently they did not look at it. The texts of the two editions are identical, except for differences in abbreviations and an occasional, obviously typographical error. There are significant differences, discussed below, in some of the figures; the figures used here are from the first edition. There is no surviving manuscript that I know of.

The *Sixteen Problems* is a straightforward didactic set of problems for determining the location and size of comets from measurements and quantitative computations of their daily parallax. It is a theoretical treatment with assumptions clearly stated and with no reference to any particular comet.

The objectives are clear, but the example, as it were, is lacking. Regiomontanus' style is clear and laconic. He does not go into detailed proofs, but assumes his reader knows that when three independent elements of a spherical triangle are known, the triangle itself is known. His proofs are elegant and economical. It is only when he is giving a general verbal discussion rather than a proof that he tends toward prolixity. Although his emphasis on measuring distance is quite new and would lead to the downfall of Aristotle's system, there is no allusion to that possibility in the treatise itself.

FIRST PROBLEM

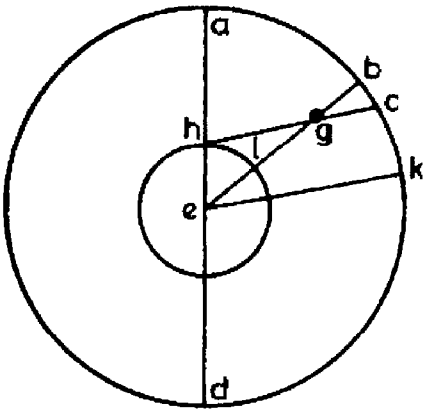
In the first problem Regiomontanus defines his terms and describes the general method. He points out that the true place B of the comet, that is, the place of the comet on the celestial sphere as seen from the center of the earth, will always be higher in the sky than the apparent place C, and that the interval BC between the two places measured along the altitude circle, will be greater the lower in the sky the comet is. In the daily rotation, the true place will trace out a small-circle path on the celestial sphere parallel to the celestial equator. Thus the deviation of the comet's apparent path from this small-circle path will give a measure of the daily parallax. It is clear that the parallax will be minimum when the comet is on the meridian circle and will vanish when it is directly overhead. Regiomontanus states further that, because the earth is as a point compared to the celestial sphere, the points C and K may be taken for one another as a reasonable approximation. He concludes this introductory section by asserting the necessity of parallax determinations for computing the size and distance of comets.

SIXTEEN PROBLEMS ON THE MAGNITUDE, LONGITUDE, AND TRUE LOCATION OF COMETS, BY JOHANNES OF MONTEREGIO THE GERMAN, THE MOST LEARNED MAN ANYWHERE

First problem. Preamble to investigating the distance of a comet from earth.

Because the observer is distant by a certain amount from the center of the earth, and the center of the comet is removed from both of these, three straight lines coming together at angles are necessary to join the three points, unless one of them is located somewhere in the direction of the other two, that is, when one and the same straight line contains the three points, which happens when the comet is vertically overhead, for then the true place of the comet is the same as its apparent place. The comet being elsewhere, these two places always differ, the more the farther the comet is removed from overhead. Moreover the true place of the comet, not overhead, is nearer to overhead than the apparent place. From the center of the earth and the observer two straight lines are extended intersecting at the center of the comet, and extended further until they define two points on the *primum mobile*, which is centered on the center of the earth. Even if, before they reach the comet, the line from the center is lower than the line from the observer, nevertheless beyond the comet they are seen reversed. The figure shows this properly. Let the circle ABCD represent a great/sphere with respect to which the size of the earth can be considered negligible. At the center is E. A great circle containing points H and L

represents the sphere of the earth, where H is the observer on the surface of the earth and the earth's radius EH extends in both directions to the circle ABCD intersecting it in two [fol. 1 v] points: A the upper one, D the lower one. A will be the point directly overhead. And if the center of the comet is at point G, not on the diameter AD, two straight lines are extended from E and H through G making points B and C on the surrounding circle. And B, the true place of



the comet, will be nearer point A than C, its apparent place. But if we place the comet on AD, the diameter, there is no doubt that the true place does not differ from the apparent place. If the radius EK is produced parallel to line HG, point K is insensibly removed from point C because the whole earth can be considered as a point with respect to ABCD, as Ptolemy reasoned in his fifth great book on the parallax of the moon. Thus it does no harm to take the two points C and K freely one for the other. Although the center of the comet appears at point C to the eye at H, nevertheless point K can become known to an observer using an instrument, for the angle AHC, taken with the instrument, is equal to the angle AEK. Since the vertex of AEK is at the center of the circle ABCD, its proportion to four right angles is known and the ratio of the arc AK with respect to the whole circumference is revealed. But since the position of A is given, the position of K will be known. But angle AHC corresponds with point C. No one can investigate this closely unless first he decides the proportion of the earth's radius EH to the radius EA. If therefore you should take point C, the apparent place, for point K, nothing will be lost that should hinder us in the following exposition. For mortals agree not to empty straight away the treasures of nature but, in most of what can be known, to get acquainted with an approximation to truth. Similarly, if arc BC, which joins the true with the apparent place, is defined as the parallax of the comet, arc BK deserves to be given the same name, parallax, since it differs insensibly from that arc BC, [fol. 2 r] and since this approximation may enable us to reach the solution we seek, as will be explained below. Now we argue that, as mentioned before, inquiring into the comet's parallax is a work of great value; indeed, if this is neglected, neither the distance between the comet and the center of the world, nor the comet's size, nor other things of this kind can be measured.

SECOND PROBLEM

In the second problem Regiomontanus takes the most general case, in which two observations of the comet are made, both on the same side of the meridian. From the observations he knows two apparent altitudes and azimuths, the time interval between the two observations, and the terrestrial latitude. In terms of the figure, he knows ZO and angle BZO, ZM and angle

BZM, angle GHL, and ZH. From these he wants to find GO and LM, the two parallaxes. Note that because he knows the time between the two observations, he knows the angle GHL between the two true places, even though he does not know where on the arcs ZO and ZM the true places are to begin with. In presenting this problem, as in all the other problems, he assumes the reader is familiar with procedures for solving spherical triangles when three independent elements are known. In the present proof, he starts with triangle ZOH, where ZO, ZH, and angle OZH, the supplement of the azimuth BZO, are known. He then solves successively triangle ZHN, triangle MZN, and triangle LMN, which gives him LM and LN. But since LN is equal to GO, he has found both the parallaxes he sought. This is an extremely neat and economical proof. There are no digressions.

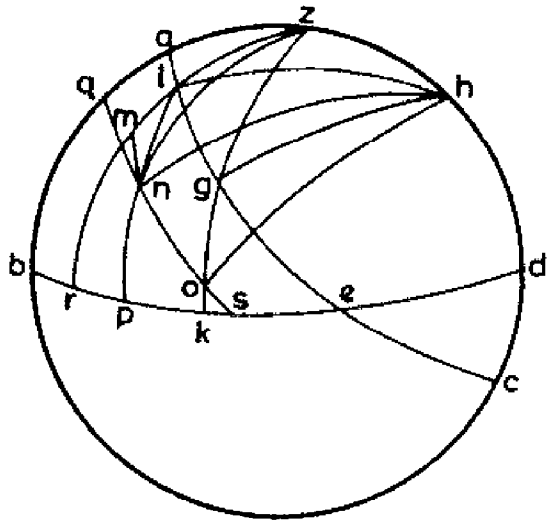
I should like to emphasize here that both in setting up the problem and in stating the conclusion Regiomontanus insists that "the comet did not move during the time interval between the two observations except by the *primum mobile*". Thus he explicitly assumes that the comet is carried around by the daily rotation and that it has no proper motion. He restates this assumption again and again throughout the text.

There are significant errors in the figure for this problem as it appears in the second edition, but in the first edition the drawing is correct. In the second edition the great circle arc LN has been omitted and the great circle arc HO has been erroneously drawn HK; point O should be the intersection of arcs ZK, QS, and HO, as indeed it is in the first edition. The text in the second edition is correct.

Second problem. Inquiry into the comet's parallax in the altitude circle.

First we observe most carefully two altitudes of the comet with their azimuths, both either before the meridian or after the meridian. We will proceed by means of these observations. Let the meridian circle be ABCD and the eastern half of the horizon be BED. The true place of the comet is at point G. On the quadrant ZK from the zenith Z through the true place of the comet in the sky, the apparent place of the comet is indicated by point O, for the true place and the apparent must always be perceived in the same circle of altitude. The true semidiurnal arc of the comet is AE and the semidiurnal arc of point O is QS. Finally, from the north pole of the world H, two great circle arcs HG and HO are extended. This has to do with the first observation. In the second observation, L represents the true place of the comet, through which from the zenith Z descends the great circle quadrant ZLR. I draw great circle arc HL which will be equal to arc HG, [fol. 2 v] and arc HN equal to arc HO, making angle LHN equal to angle GHO; this follows plainly from the fact that, just as in the time interval between the two observations point G is moved by means of the *primum mobile* to place L, likewise point O is moved to place N, since the two angles GHL and OHN are equal to each other. However we imagine the comet to be moved only by the motion of the *primum mobile* in that time.Therefore from the zenith drop a great circle quadrant ZP through that point N. The apparent place of the comet in the second observation is marked point M. Then the two great circle arcs LN and MN are joined. Now we are getting deep into the argument. From the first observation are known arc ZO, which is the distance of the apparent place from overhead, and angle BZK; ZH, the complement of the latitude, is also known. Triangle ZOH therefore has two sides and one angle known, from which arc HO, angle ZHO, which is the distance of point O from the meridian, and angle HOZ become known. Moreover, since the time interval between the two observations is known, angle

GHL will be known and equal to NHO; therefore the leftover angle ZHN will be known. Moreover both of the arcs ZH and HN are known, whereby the arc ZN can be known with angles ZNH and NZH. Likewise, through the second observation, arc ZM is learned together with angle BZR. If angle BZR is subtracted from angle BZP, known because angle NZH is known, angle MZN remains and is known. Since the two arcs ZM and ZN are known, arc MN will be known with the two angles ZMN and ZNM. Moreover the two triangles LHN and



GHO are equilateral and equiangular, and angle GOH, long since known, is equal to LNH. Likewise angle ZNH has been established as known; angle MNH is thus the sum of two known angles, and if you subtract from it angle LNH, the remaining angle LNM is then known. And so the triangle LMN and side MN have been measured with the two angles LMN and [fol. 3 r] LNM, whence both of the arcs LM and LN can be known. However arc LN, equal to arc GO, was the parallax in the first observation, and arc LM is the parallax of the comet in the second observation. So we are finished. All this, however, as we showed above, supposes that the comet did not move during the time interval between the two observations except by the *primum mobile*; but if it did move, yet in so very brief a time its own proper motion would be hardly sensible. Arc HG, the true distance of the comet from the pole of the world, would be changed imperceptibly.

THIRD PROBLEM

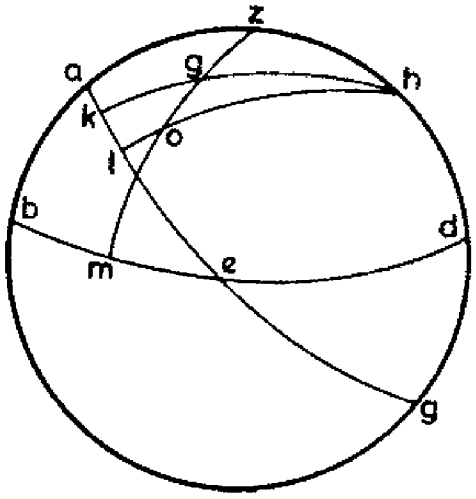
The third problem uses the special and easier case where one of the observations is at the meridian to find the parallax of the comet at the non-meridian observation. Here, because he knows ZO from observation, Regiomontanus has only to find ZH by solving the single triangle ZGH in order to obtain OG, the desired parallax. In triangle ZGH, ZH is known from the terrestrial latitude, angle GZH from the observed azimuth, and angle GHZ because the time between observations is known. At the end of this problem he returns again to the possibility that the comet has a proper motion. He gives a way of approximately correcting for it: take the proper motion of one whole day, find the proportion of that appropriate for the time interval between observations, and make the necessary adjustment in

the size of the angle GHZ. This assumes that the proper motion, if any, will be uniform.

The figure for this problem in both the first and the second editions has G as the point where the equator intersects the meridian, where the text clearly indicates the letter C is meant. (The letter G is always used for the comet.) In addition, the letter Z at the zenith has been omitted in the second edition.

Third problem. To conclude the same thing in another way.

The altitude of the comet and its azimuth arc are taken either before meridian or after meridian, and the exact time of this observation is noted, together with the exact time that the comet passes the meridian. This is easily done through observation of any fixed star having a known place. Therefore the time interval between the two observations will be known. Thus now let the meridian circle be ABCD; the eastern half of the horizon is BED, half of the equator is AEC, and the true place of the comet at the before-meridian observation is at point G. From the zenith Z the great circle quadrant ZM is dropped through point G, and on it is the apparent place of the comet, point O. Then from the north pole of the world H, two great circle quadrants HK and HL are passed through the two points G and O. Since [fol. 3 v] the time



between the two observations is known, angle GHZ will be known. Moreover, because the azimuth, the angle GHZ, and the upper arc ZH which is the complement of the latitude of the region, are all known, triangle GHZ is known, because one side and its two enclosing angles are known. The other side GZ then becomes known. Arc OZ, which is the apparent distance of the comet from directly overhead, is known by instrument from the observation. Therefore the remaining arc GO, which is the parallax of the comet in the altitude circle, is known. The reasoning would be no different if a post-meridian observation were used. In case you suspect the proper motion of the comet of introducing some error, you can satisfy your mind this way: Take the comet's proper motion in one natural day. From this you learn how much its proper motion is for the time interval between the two observations, from which you easily can determine how much of the equator this corresponds to; according to the size of angle GHZ you determine if the angle should be greater or smaller. To determine the true proper motion of the comet in a natural day, consider the true place of the comet at the beginning of its appearance and its true place at the end of its appearance, and distribute the space crossed by the comet in the number of days in between; thus you will have the comet's approximate daily motion which you sought.

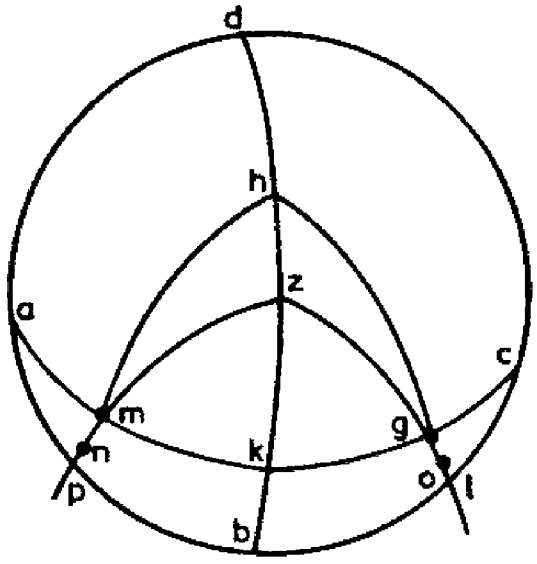
FOURTH PROBLEM

This problem treats another special case in which the two obseravtions are made at the same altitude, obviously one before and one after meridian. Regiomontanus says that this is useful when the comet passes the meridian during the daytime; we would then have one early morning and one evening observation, with the time between the two observations known as usual. In this case as with the others, it is clear that he measures the time interval by the positions of known fixed stars, not by any kind of clock. He concludes by pointing out that in this problem he has determined the comet's declination from the equator and its position in the ecliptic.

The lettering of the figure for this problem presents some minor difficulties. In this instance it appears that the figure from the first edition is correct and the text is in error. According to the text there would be two points designated K, one where the comet's diurnal arc intersects the meridian, labeled K on the figure, and one where the altitude circle through point M intersects the horizon, labeled P on the figure. It is not at all difficult to follow the proof, however, despite the ambiguity in the labeling. The second edition omits the letter L from the intersection of the altitude circle through G and the horizon.

Fourth problem. To prove what went before by another argument.

The comet sometimes crosses the meridian when the sun is above the horizon and therefore it cannot be seen. Nevertheless, the computation can be done if the comet is seen both before sunrise and after sunset [fol. 4 r] even though there is no meridian observation at all. We will explain the reasoning. We consider two equal altitudes of the comet, one before meridian and

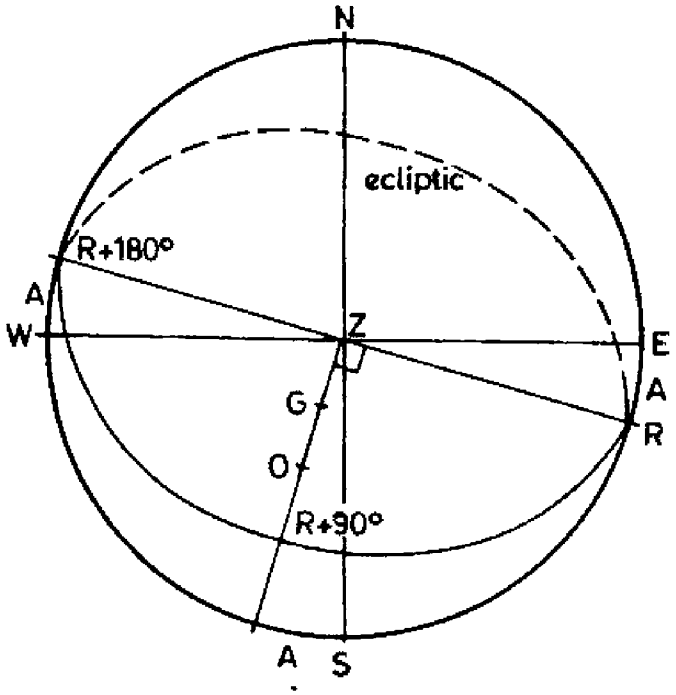


one after meridian, with the azimuth degrees. We use the configuration in which the horizon circle is ABCD, the semicircle of the meridian is DZB, the comet's diurnal arc, which describes its being carried around by the *primum mobile*, is CKA, and the true place of the comet is first at G, the before-meridian point, and then at M, the after-meridian point. From the zenith Z two great circle quadrants ZL and [ZP] are extended through points G and M. Point O is the

comet's apparent place before meridian, and point N is its apparent place after meridian; arcs OL and [NP] are equal, as mentioned above, so that to proceed it is only necessary that in addition the two arcs GL and [MP] are found to be equal to one another. If from the north pole of the world to the two points G and M you produce two great circle arcs, these can be shown to be equal by geometry. It is necessary to know the time between the two observations, which will not be difficult to establish by some known fixed star, so that both the arc GM and the angle GZM are known. From angle GZM, angle GHK or GHZ becomes known because both of them are half [*medietas anguli*] of angle GZM. Besides, angle GZK was taken by instrument as discussed above; its magnitude is determined by the azimuth arc, and so [fol. 4 v] its supplement, the angle GZH, will be known. Since arc ZH is the complement of the altitude of the north pole, the triangle GZH will be known because the two angles GZH and GHZ and the side HZ are known. However arc ZO was known by observation; therefore you know the remainder GO, the comet's parallax in the altitude circle, which you sought. But this again supposes that the comet does not move sensibly by its own motion during the time interval between the two observations. If therefore you wish to correct for its own motion, do so in the manner we described above. Otherwise, from this procedure the true declination of the comet from the equator is established, for arc HG is the complement of the declination. And because angle GHK was known since the moment of observation, the position of the comet in the ecliptic can be computed. Thus the position of the comet in the ecliptic and its latitude can be derived.

FIFTH PROBLEM

Unfortunately, the fifth problem does not have a figure, which makes the text rather difficult to follow. Consider the following figure in which NESW is the horizon circle, NZS the meridian circle, R the rising point of the



comet, A the amplitude of R, the angular distance along the horizon from true east, G and O the comet's true and apparent places when it is "one fourth of the ecliptic from its rising point, according to longitude in the ecliptic". Altitude circles appear in this figure as radii of the horizon circle.

Note that only at R + 90° is the altitude circle perpendicular to the ecliptic so that the longitudinal component of the parallax vanishes. It is in this sense that Regiomontanus means that the true position will not differ from the apparent position; there will still be a parallax component in latitude unless the comet happens to be at zenith.

Fifth problem. To find the comet's true position in the ecliptic, using an instrument.

Consider the comet when it is one-fourth of the ecliptic from its rising point, according to longitude in the ecliptic. In that position its true place will not differ from its apparent place, and its apparent place can be determined by an armillary instrument or some other instrument of that type; its true place as well. However because it is difficult to determine that position of the comet, I suggest considering the distance between a point 90° from the ascending place and the meridian according to divisions of the horizon, and the amplitude of the ascending place. A geometrical [fol. 5 r] demonstration is given elsewhere. Make your observation therefore when the comet's distance from the meridian according to horizon degrees is equal to the amplitude of the ascending place, for then by adapting the instrument to some known star, the comet's true position, which was sought, will be established.

SIXTH PROBLEM

Once we have the comet's true longitude from problem 5, we can determine the parallax in longitude from a second observation which will give the apparent place in the ecliptic. Again Regiomontanus states the assumption that there is no proper motion but gives a general statement of the procedure for estimating the correction for uniform proper motion.

Sixth problem. To measure the comet's parallax in longitude.

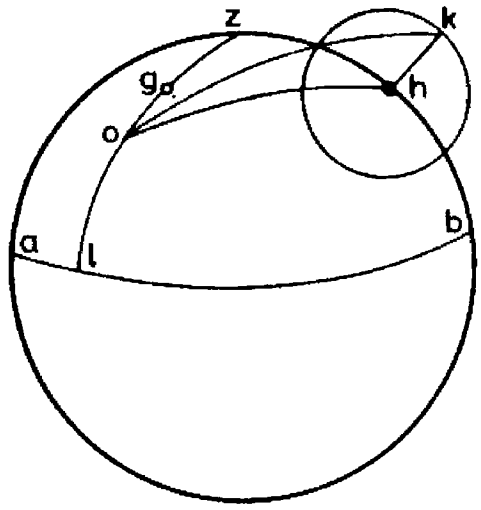
From the preceding you have the comet's true position. If you observe the comet at other than 90° from the ascending place, the instrument will give its apparent place. The interval between the true and the apparent places, which is called the parallax in longitude, thus becomes known. If the comet's proper motion in the time between the two observations is appreciable, you should remember those things which we showed above. For through the comet's own motion in the time interval between the two observations, the true position can be determined either by addition to, or by subtraction from, the second observation.

SEVENTH PROBLEM

In the seventh problem Regiomontanus explains how to determine the comet's apparent latitude from a single observation of altitude, azimuth, and time of observation. In terms of the figure given, ZO, angle OZH, and angle OHZ are known from the observation, ZH is known from the terrestrial latitude, therefore triangle OZH is known, yielding OH. Triangle OHK can then be solved because the position of K, the pole of the ecliptic, on the arctic circle is known with respect to the meridian; i.e., both HK and angle ZHK are known. And since angle OHZ is known both from the time of observation and from the solution of triangle OZH, the entire angle OHK is known. From the solution of triangle OHK, side OK, which is the complement of the comet's apparent latitude; is known. This method, he says, is simpler than Ptolemy's on the observation of the moon.

Seventh problem. To investigate the comet's apparent latitude, if any.

By means of an instrument set by some fixed star as usual, you can easily obtain the desired latitude of the comet, if you follow the teachings of Ptolemy on the observation of the moon. If however you wish to arrive at a simpler observation, consider the comet's apparent distance from overhead and its azimuth and the altitude of a known fixed star [fol. 5 v] so that the time of observation is known. I draw the meridian circle ABHZ, and the eastern half of the



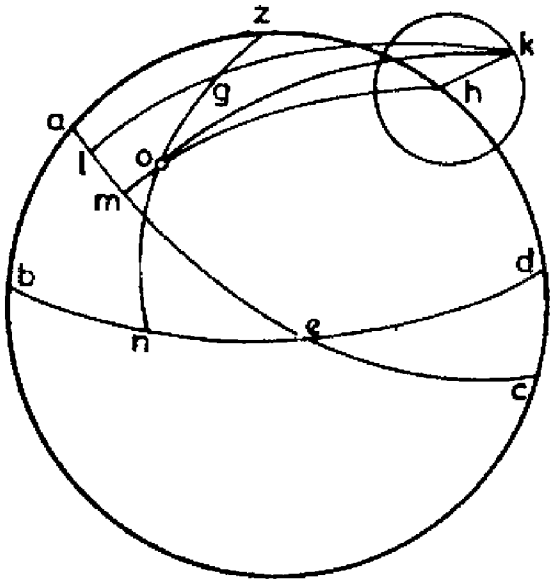
horizon ALB; the comet's apparent place is point O through which descends from the zenith Z the quadrant ZL. The north pole of the world is H around which the arctic circle is drawn, and on its circumference is the pole of the ecliptic K. Three arcs OK, OH, and HK are drawn. From arc ZO and angle OZH, known from observation, and ZH, the complement of the pole's altitude, arc OH which is the complement of the comet's apparent declination will be known. Angle ZHO is known because the moment of observation is known, and the point of the ecliptic which is on the meridian will be established. And since arc HK extended beyond K crosses through the beginning of Capricorn, the right ascension corresponding to the arc of the ecliptic between the beginning of Capricorn and the mid-heaven [intersection of ecliptic and meridian] will be known. However, this right ascension determines angle ZHK and makes it known; adding this amount to angle ZHO, the whole angle OHK becomes known. But arc HK is equal to the maximum declination of the sun, and arc OH has been determined, so arc OK, whose complement is the comet's apparent latitude, which we sought, may also be found. Angle HKO, which corresponds to the distance of the comet's apparent place in the ecliptic from the beginning of Cancer, was found above, by which means finally the comet's apparent place in the ecliptic will be known. But although the pole K of the ecliptic may be located in different places on the Arctic circle, it will still be possible to derive angle OHK; sometimes it will be necessary to subtract angle ZHK from angle OHZ; angle OHK, the remainder, is then known. In the present figure, the two angles are necessarily related. [fol. 6 r]

EIGHTH PROBLEM

The eighth problem depends on the fifth and sixth problems; it determines the comet's parallax in another way. Using arc LM, determined in problem five, Regiomontanus first solves triangle KLM. Then, as usual, he solves successively triangles OHZ, OHK, and finally GOK which yields GO, the parallax in the altitude circle, and GK, the complement of the latitude from the ecliptic. This is the last of the series of related problems determining parallax in the different coordinate systems.

Eighth problem. To investigate the comet's parallax in the altitude circle in another way.

The meridian circle is represented as ABCD, under which is the eastern half of the horizon BED, and half of the ecliptic AEC. The comet's true place is G, the apparent place O, and both of these are located on the quadrant ZN descending from the zenith Z. The north pole of the world is H, around it the arctic circle, and on its circumference point K represents the north pole of the ecliptic from which two great circle quadrants KL and KM advance through the two points G and O, ending on the ecliptic. So L will be the comet's true place in the ecliptic, and



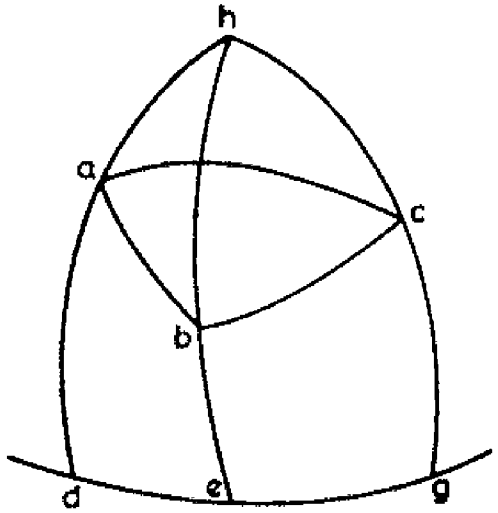
arc LM which is the comet's parallax in longitude, is known from above. This arc LM determines the size of angle [GKO] [the text reads GOK in both editions] by which means this angle is known also. I draw arc HO. I know from observation arc ZO, the distance of the comet's apparent place from overhead, and angle OHZ, known by instrument; so both of the angles ZOH and ZHO will be known together with arc HO. Hence from triangle OHK, known because two sides OH and HK and angle OHK are known, as in the preceding, angle HOK and arc OK, the complement of the apparent latitude, become known. Then subtracting angle HOK from angle ZOH, the remaining angle GOK is known. Angle GKO was known previously. Therefore triangle GOK, with two angles [fol. 6 v] and side OK known, will reveal arc GO, the comet's parallax in the altitude circle, which was sought. Finally from the same triangle, arc GK is known and thus also arc GL, the comet's true latitude from the ecliptic. Indeed, as the figure shows, if arc GK is discovered to be a quadrant, the comet's true place is established in the ecliptic without latitude.

NINTH PROBLEM

Whereas all the preceding problems have begun with altitude, azimuth, and time observations, this one depends only on measuring the distance between the comet and two known fixed stars, then triangulating to find the apparent location. This is in fact the method Regiomontanus himself uses in the one cometary observation we have, from January 20, 1472 (see below). Once the apparent place is determined using this method, the altitude and azimuth are computed for the time of observation noted by the altitude of one of the fixed stars. At the conclusion of this problem Regiomontanus refers us to his "little book on spherical triangles" for other approaches.

Ninth problem. To determine the comet's apparent position simply.

Two fixed stars near the comet are observed and the distance of the comet's apparent place from each of the two is measured. In the figure one of the two stars being considered is A, the other B, the portion of the ecliptic in which the two stars are located is DG, the pole of the ecliptic is H, and two great circle quadrants HD and HE descend through points A and B. The comet's apparent place is C, through which is drawn a great circle quadrant HG from the pole of the ecliptic. Thus G will be the comet's apparent position in the ecliptic which we seek and arc GC will be its apparent latitude. Three great circle arcs AB, AC, and BC are drawn. Because the two stars A and B have their positions in the ecliptic and their latitudes known, arc DE, which determines the size of angle DHE or AHB, will be known. Finally the two latitudes AD and BE and their complements AH and BH are known, so you have triangle AHB with two sides AH and [fol. 7 r] HB and angle AHB known. Thus side AB, the distance between the two



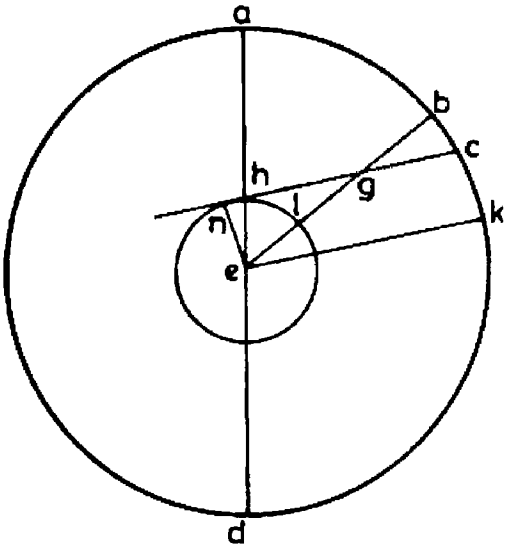
stars, and angle BAH are determined. Then since the two arcs AC and BC are determined by observation, and AB has been found by derivation, all three sides of triangle ABC are known, and therefore angle BAC can be found. If you subtract this from angle BAH, previously known, angle HAC remains and is known. Thus triangle HAC, having two sides HA and AC and angle HAC known, yields angle AHC and arc HC. However angle AHC [text: HAC] determines the size of arc DG, by which means it also is known. Because point D was known, point G is now known. Thus we have managed to find the comet's apparent place in longitude in the ecliptic. Furthermore, arc CG, the apparent latitude, is determined because its complement HC is known. Finally we have both the comet's apparent place and its apparent latitude, which is a pleasing result. It is possible to approach the problem with other sorts of figures, but the argument will not differ much. Our little book on spherical triangles will furnish other figures, if you wish to try others.

TENTH PROBLEM

With problem ten we come finally to the point of these exercises in parallax: to find the distance of the comet from the earth using the value of parallax determined by one of the preceding problems. Here for the first time Regiomontanus uses the assumption, introduced in the first problem, that the earth's size is negligible so that C and K effectively coincide. He constructs the right triangle EHN and establishes the ratios of its sides. Then it is perfectly staightforward to find EG and HG in relation to EH, the earth's radius.

Tenth problem. To measure the comet's distance from the center of the world and from the observer.

The circle of altitude ABCD constructed around center E represents a great circle with respect to which the earth can be considered as a point. Circle HL represents the earth, diameter AD passes through point A directly overhead, and H represents the observer on the earth's surface. Let G be the comet's center and extend two lines through the comet's center, [fol. 7 v] EB from the center of the world, and HC from the observer, to meet the great circle at points B and C. Now it is agreed that B is the comet's true place, C is the apparent place, and arc BC is



defined as the parallax in the altitude circle; and if, finally, EK is drawn out from the center of the earth parallel to HC, point K insensibly differs from from point C as we explained in problem one. We seek therefore the two lines EG and HG, one of which, EG, signifies the distance of the comet from the center of the world, and the other, HG, denotes its distance from the observer. We seek them according to some accepted or known measure, namely with respect to the earth's radius EH. We proceed as follows: Extend line GH to where EN coming from the center of the earth hits it perpendicularly. By observation angle AHG and hence its vertical angle EHN are known; point H serves as the center of the instrument. Thus, in triangle EHN, the right proportion of line HE to both straight lines EN and NH is known. Also by the many arguments expressed above, we have measured arc BK, which is equal to angle BEK, so its alternate interior angle EGN is known. Therefore in triangle GEN, the proportion of GE to both lines EN and NG is known. Since the ratio of both of the two lines GE and EH to the perpendicular EN is known, their ratio to one another is known as well. Thus the comet's distance from the center of the world is revealed. But because the ratio of GE to GN was known, the ratio of NG to HE is also known. [fol. 8 r] But we already know the ratio of NG to NH, so both lines GN and NG have known ratios to line EH. If we substract the smaller of them, NH, from the other, NG, line HG remains. The distance of the comet from the observer with respect to line EH, which was to be determined, is thus known.

ELEVENTH PROBLEM

Problem eleven states, in an unusually confusing manner, that, since the distances from the observer and from the earth's center to the comet are known in relation to the earth's radius, then if you know the earth's radius in miles, you know the other distances in miles as well.

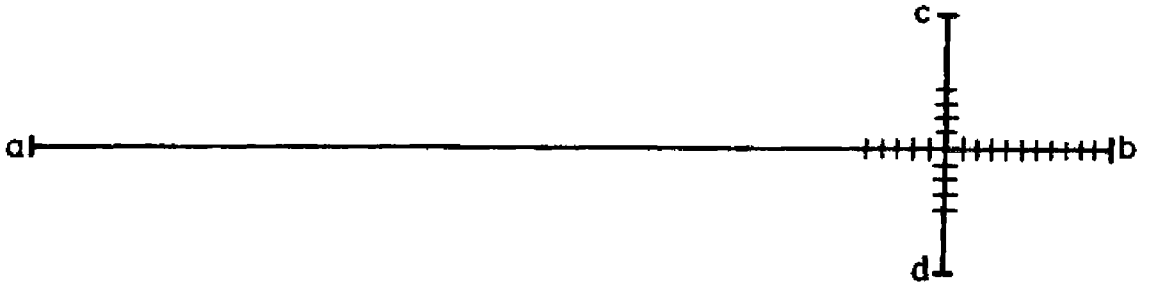
Eleventh problem. To learn the distance in miles between the comet's center and the earth's center or the observer.

It is appropriate to discuss miles or any other usual or freely assumed unit of measure. However, first the earth's radius must be known in that same measure. But I declare that the generally accepted value for this radius is hidden from no one. For who does not know how to measure the earth's radius from its circumference, by whatever unit of measure it is known? Therefore, the earth's radius being known in miles, for example, from the preceding determination of the ratio of the earth's radius to both of the distances in question, both of them may be known in miles. For the number of miles in line EH is to the number of miles in line EG as the quantity of whatever measure in line EH is to the quantity of that same measure in line EG. Thus if three of these quantities are known, the fourth belonging to the proportion, which was sought, is known.

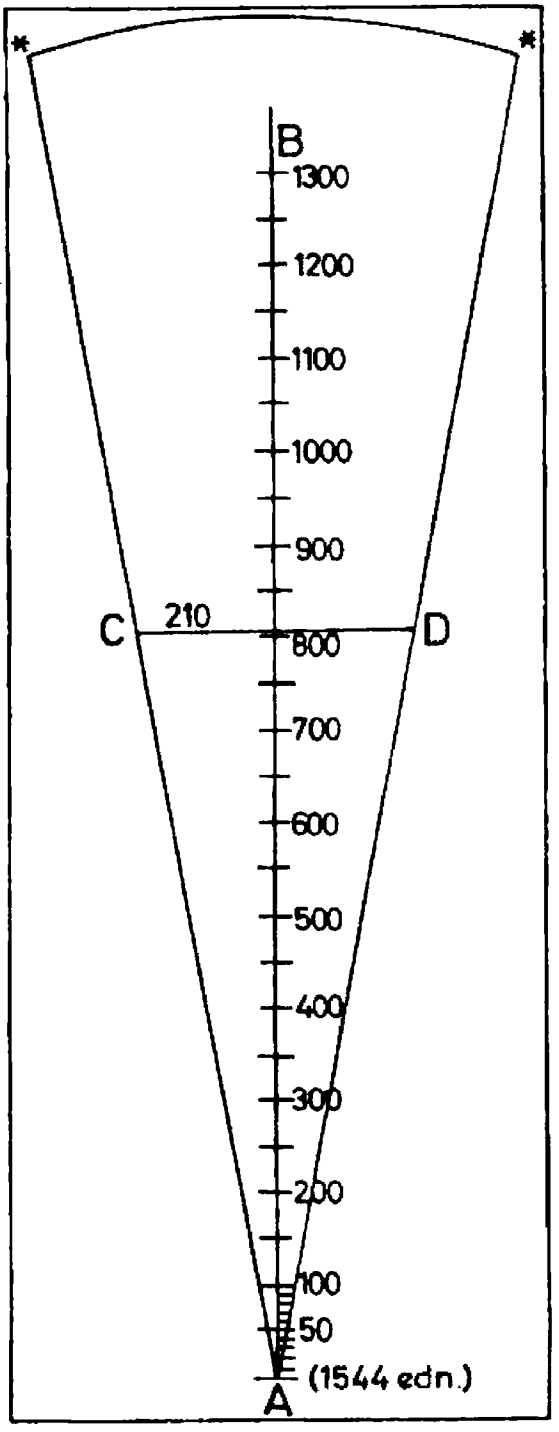
TWELFTH PROBLEM

Problem twelve is quite straightforward. It describes an instrument for measuring the comet's apparent diameter. The instrument is in fact a version of the Jacob staff or cross staff, invented and described by Levi ben Gerson (1288–1344) in chapters 4 and 5 of his astronomical treatise (Goldstein 1974: 21–23; Curtze 1898: 108–111). Many of the observations recorded in the Schöner text (1544) were made with this instrument. Regiomontanus' version is somewhat more crude in that Levi took into account the center of vision of the eye and began the scale on the long axis of the instrument about one centimeter off the end of the ruler. In his treatise Levi describes how he arrived at this experimentally (Curtze 1898: 108). Regiomontanus and Walther evidently had a copy of a Latin version of Levi's treatise and it seems curious that Regiomontanus should have disregarded this refinement.

Another difference is that the device described here is made up of two rulers at right angles, while Levi's had a square plate which traveled on a long ruler. The plate was of a fixed size (Curtze 1898). Goldstein notes that there is no figure in the text and thinks that Curtze was wrong in his interpretation. Levi's word for plate also seems to mean alidade. Levi also used a diagonal scale, not mentioned by Regiomontanus. Regiomontanus' crossbar was itself calibrated, making possible readings such as those in his observation on January 20 of the comet of 1472 (see below) where two readings are given as 953.190 and 953.210. The text gives no indication of the scale markings to be used, though it does say that the more divisions there are, the better. The figure in the first edition clearly shows that the divisions on the two rulers are to be equal but does not indicate the scale at all, whereas the second edition shows a numerical scale.



In the same volume which contains the second edition of the *Sixteen Problems* there is a short treatise by the editor of the volume, "Ioannis Schoneri in constructionem atque usum rectanguli sive radij Astronomici, annotationes" (folios 34 v – 35 v). The figure for this treatise is identical with the figure for problem twelve in the same volume. The text describes the instrument giving the scale indicated in the figure, up to 1300 on AB and up to 210 on CD with a pin, or *claviculum subtilem*, indicating every 10 units on the CD scale. In practice the instrument was pointed in the desired direction



and adjusted so that a convenient interval on CD just covered the distance between two stars or planets, or between a comet and a star, or the diameter of the comet, moon, etc. In this case, the observer found the value of 210 on CD and reading of 953 on AB. With CD set in the same position, the instrument was aligned to a different star and a new value of CD was read. Keeping the value of AB constant for the two readings would allow a direct comparison of the two distances to be made. In problem twelve Regiomontanus states that you then read the angular measurement off an appropriate table. Schöner is more specific; he refers us to the "tabulam Gnomonicam quae in Quadrato Geometrico M. Georgij Beurbachii [*sic*] ponitur".

Twelfth problem. To find the comet's apparent diameter by means of an ingenious instrument [fol. 8 v].

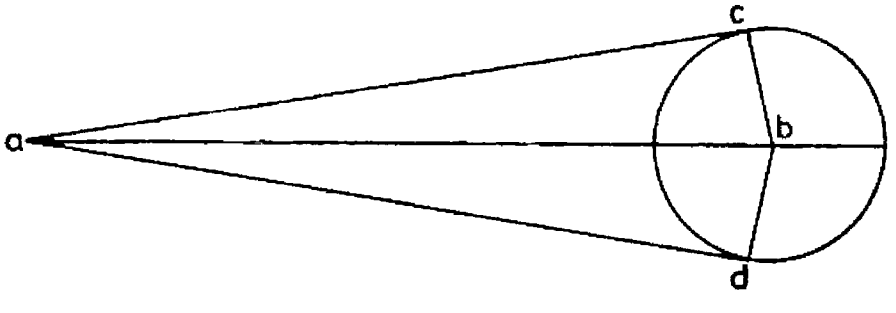
Prepare a fine ruler, five or six or more cubits long, which you divide in as many equal parts as you like; the more there are, the better it will be. We represent this by line AB, to which is joined a little ruler CD at right angles in such a way that its two arms are equal. This small ruler is movable on the ruler AB, and in its motion it always maintains right angles with AB; its divisions are the same as those we designated for ruler AB. Then at the three points A, C, and D affix three fine or sharp small keys. Use the instrument which you have thus completed in the following way: Place point A next to the right eye, keeping the left eye closed, and direct the ruler to the comet's center. This is done easily if you set it on some kind of stand. Move the little ruler CD back and forth until it covers the entire diameter of the comet. This being done, take the number of divisions which are between point A and the ruler CD and in a table arranged for this purpose, read off the apparent diameter of the comet. The construction of this table is done elsewhere. You can use such an instrument or a similar one for measuring not only a comet's diameter, but also the moon's and the sun's, provided the sunlight is not too bright.

THIRTEENTH PROBLEM

Given the comet's apparent diameter from the preceding problem, it is easy to determine its radius in relation to its distance from earth. But since this distance is known in relation to the earth's radius from problem ten, the ratio of the two radii is known.

Thirteenth problem. To compare the comet's diameter to the earth's radius [fol. 9 r].

In this problem we suppose the comet's body to be a sphere whose great circle CD has center B. The observer A is lined up with the center of circle CD, joined by line AB. Two straight lines AC and AD are drawn tangent to circle CD at the two points C and D, the end points of the two radii BC and BD. The comet is seen under angle CAD, and the arc which



subtends angle CAD is the apparent diameter of the comet. Because this is known from the preceding, angle CAD will also be known, and therefore the half, BAC; therefore, because the lines are perpendicular at C, the proportion AB to BC, the comet's radius, comes to be known. But from the above you will remember that AB was known with respect to the earth's radius. Therefore, in whatever measure the earth's radius is known, the comet's radius and diameter, which we sought in this problem, will be known in the same measure.

FOURTEENTH PROBLEM

This problem is perfectly straightforward and requires no comment.

Fourteenth problem. To measure the comet's volume.

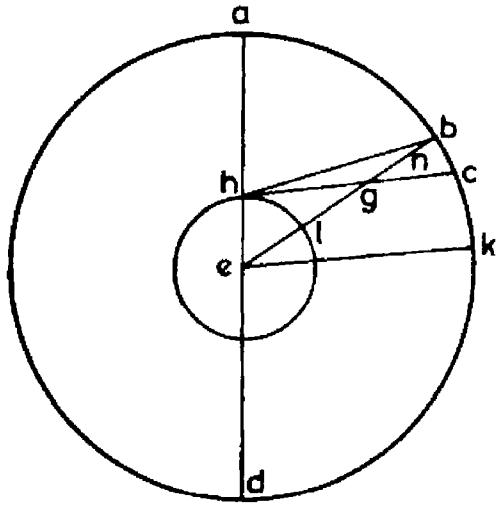
From the preceding, the ratio of the earth's and comet's diameters was established. Since the ratio of the spherical bodies is the triplicate ratio of their diameters, the comet can with certainty be compared to the earth. And because we can determine the earth's volume, the comet's volume can also be found [fol. 9 v].

FIFTEENTH PROBLEM

The comet's tail had always been of interest for astrological reasons: the direction in which it pointed was taken to indicate the region on earth of the comet's influence. In the sixteenth century this became very important as the discovery that the tail always was directed away from the sun became an argument for a sun-centered universe (see chapter VIII below). Regiomontanus' interest here is only with the length of the tail. He accepts the Aristotelian assumption that the comet's tail is of the same substance as the head, only lighter. It follows, then, that the tail is oriented along a radius of the universe away from its center. In the figure, the tail GN lies along the radius EGB. The length of GN with respect to the earth's radius is then found by methods already used. The figure in the edition of 1544 suggests that N coincides with B, which it does not. The figure in the first edition is more carefully drawn.

Fifteenth problem. To inquire into the length of the comet's tail.

Before we approach this problem, it is necessary to understand that the comet's tail does not differ in substance from the comet's body, but is rarer and lighter; because of its rarity light shines through it, and because of its lightness it is said to extend above. To estimate its length, a straight line is drawn from the earth's center to the comet's center and extended beyond it through the middle of the tail, as if it were the axis of the cone of smoke which they call the comet's tail. The angle which the tail itself subtends at the observer is determined with an instrument; this is done easily using the sort of instrument described above. Now for the proposed solution, I draw the great circle ABCD, with respect to which the circle of the earth HL has negligible size. The earth's center is E, the two points A and D terminate the diameter AD, of which the upper one A is above the top of the head. The other is at the opposite place. The observer is at H, from which and from the earth's center E are drawn two straight lines, one of which, EB, designates the comet's true place, point B. The other, HC, indicates the comet's apparent place, point C. EK is drawn parallel to HC. Therefore arc BK differs insensibly from arc BC, the parallax of the comet, as shown above, whence also angles BEK and [fol. 10 r] EGH are known. Finally let the length of the tail be GN subtending the angle of vision GHN, measured with the aid of an instrument, and draw the straight line HN. Triangle GHN will have



two known angles at G and H, at G because angle EGH is known and at H by instrument. You remember that side HG was determined above and so side GN, the length of the tail, will be known. Next, line GN is to be compared to the earth's radius, by an intermediate assumption. We have already measured line GN with respect to line HG; this however was found above in relation to EH. Therefore GN itself will have been measured with respect to EH, which was desired.

SIXTEENTH PROBLEM

In this problem Regiomontanus assumes that the tail must be either a cylinder or a cone whose base is the comet; we know the diameter of the base from problem 13. Then if d is the diameter of the base and L is the length of the tail from problem 15, he says, the area of a square surrounding a circle, d^2, is to the area of that circle, $\pi d^2/4$, as the volume of a quadrilateral column of length L on that square base, $d^2\,L$, is to the volume of a cylinder of length L on that circular base, $\pi d^2\,L/4$, or as 14 is to 11. Or:

$$\frac{d^2}{\pi d^2/4} = \frac{d^2\,L}{\pi d^2\,L/4} = \frac{4}{\pi} \simeq \frac{14}{11}$$

and further, that the ratio of the volume of a cone to the volume of a cylinder having the same base is 1/3.

Sixteenth problem. To find the volume of the tail.

It is appropriate that the tail be rounded, so its form will be either cylindrical or conical. If it is cylindrical, we draw out the comet's known diameter into tail's length. The quadrilateral column created this way will be in proportion to the comet's tail as the square surrounding a circle is to the circle itself, which is approximately as fourteen to eleven. Therefore the volume of a cylinder of this sort is known because we know the quadrilateral column. But if the tail is a cone having its base in the body of the comet and its vertex upward, we may find the volume of the cylinder as just shown and we compute one third of it as the volume of the tail. For a cylinder having the same base as a cone has been shown to be its triple.

THE COMET OF 1472: REGIOMONTANUS' OBSERVATION

This is the next-to-last of a series of dated observations of eclipses, conjunctions, and planetary positions in the section of *Scripta clarissimi...*, 1544, entitled *Ioannis de Monteregio, Georgii Peurbachii, Bernardi Waltheri ac*

aliorum, Eclipsium, Cometarum, Planetarum ac Fixarum obseruationes, folios 36 r–43 v. The text is as follows:

Anno 1472

Norimbergae die 20. Ianuarij, hora 10. a meridie, Cometa videbatur in recta linea cum quinta Bootis, & prima informatarum iuxta ursam maiorem, distantiaque eiusdem Comete, a dicta quinta Bootis subtripla ferme erat totius dictarum stellarum intercapedinis, cauda porrigebatur ad sextum propre Leonis, citraque parum descrivit. paulo sub prima informata ad meridiem declinans 953.190. Distantia Cometae a cauda Ursae maioris, 953.210 distantia Cometae a prima earum, quae non sunt in forma.

Or, in my translation:

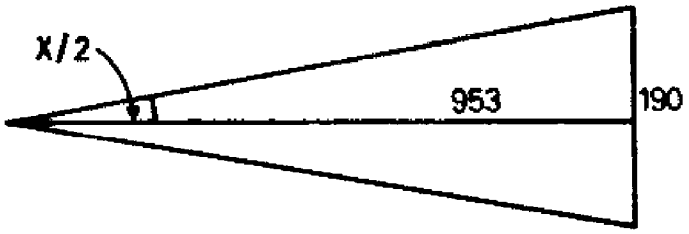
Year 1472

Nuremberg, 20 January, tenth hour after noon. A comet was seen on a straight line with the fifth star of Bootes and the first of the unformed stars near Ursa major; and the distance of the comet from Bootes 5 was about one-third of the whole distance between the two stars. The tail extended to the sixth degree of Leo ending a little to the nearer side of it, just below the first of the unformed stars; it turned aside toward the meridian. The comet's distance from the tail of Ursa major was 953.190. The comet's distance from the first of the unformed stars was 953.210.

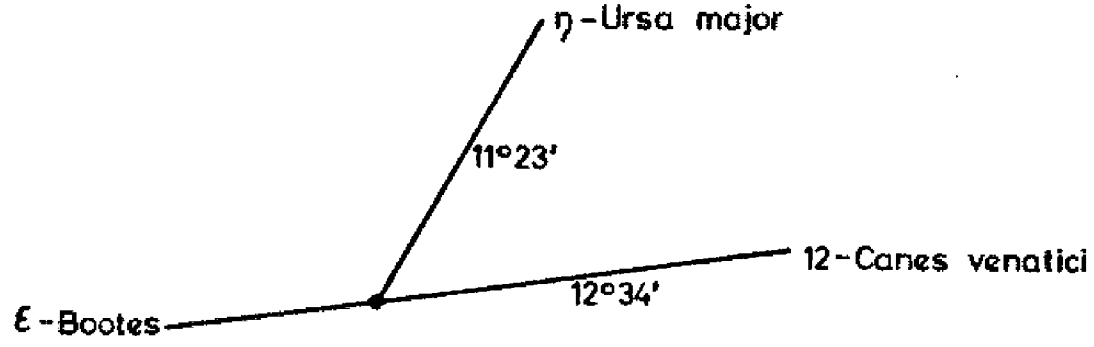
The "first of the unformed stars near Ursa major" appears in Ptolemy's star list and corresponds to what we now call 12-Canes venatici (Ptolemy's position: longitude Leo 27°50′, latitude +39°45′, magnitude 3, Baily n° 36; Peters 1915: 28). In order to understand the distance values given above, it is necessary to refer to problem 12 in the *Sixteen Problems*. Using the figure from the second edition, it is clear that:

$$\tan(x/2) = (190/2)/953 \quad \text{or} \quad x = 11°23'$$

$$\tan(y/2) = (210/2)/953 \quad \text{or} \quad y = 12°34'$$



The configuration was approximately as follows:



This is the information required for determining the comet's apparent position according to the method described in problem 9 of the *Sixteen Problems*. And it is just the kind of quantitative observation which would be needed for a parallax determination as described in these problems. Unfortunately, however, it is only a single observation, and Regiomontanus specifies that two are required.

THE COMET OF 1472: TREATISE "DE COMETIS"

This treatise was first published in this form and under Regiomontanus' name by Jakob Ziegler in 1548 as a part of his exposition of the history of the universe (Zinner 1968: 207). It was republished several times later in the sixteenth and seventeenth centuries (Hellman 1944: 82–83). One of these editions was as an appendix to the *Dialexis de novae et prius incognitae stellae inusitate magnitudinis & splendidissimi luminis apparitione, & de eiusdem stellae vero loco constituendo* per Thaddaeum Hagecium ab Hayck [Hajek], Francofurti ad Moenum, 1574. This is the edition I used; Yale has a facsimile dated 1967, Prague, in the Beineke Library. The treatise appears on pages 146–149. Hevelius quoted this treatise *in toto* in his *Cometographia* (1668) and Pingré (1783) and Celoria (1921) used Hevelius' rendition of it.

ATTRIBUTION

The style of the treatise and the quality of the observations first made me question whether this was really Regiomontanus' work. I later found a treatise on the comet of 1472 by an unnamed physician of Zurich, *Thurecensis phisici tractatus de cometis* (Yale Medical Historical Library, incunabula), published some time after April 1472 at Beromunster and again in 1474 by H. Aurl probably at Venice, both editions during Regiomontanus' lifetime. I shall refer to it as edition Z; it is a rather long work in two parts, forty-one sections, five of which are verbatim the same as the five sections of the Regiomontanus treatise (which I shall refer to as edition R). The first part is a general discussion on comets divided in twenty-two sections; the second part is specific to the comet of 1472 and is in nineteen sections. The correlation between the sections of the two works is as follows:

	edition R	edition Z
de motu comete	1	II,4
de motu caude	2	II,5
de distancia comete a terra	3	II,6
quomodo inveniatur magnitudo cometarum	4	I,10
de magnitudine comete	5	II,7

Regiomontanus' treatise has three closing sentences, after the asterisks in the text, but nothing else that is not a part of the work by the physician of

Zurich. The major difference between the two works as a whole is of course that of size and scope. The order of paragraphs in edition R is logical and it is a complete work. What is missing is all discussion of the composition of comets, their formation, their kinds, their significance, the ways in which they affect the earth, etc. It is simply a matter-of-fact description of this comet and an estimation of its size and distance, with the general method for determining magnitude inserted at the appropriate point. The style seems to be consistent within the larger edition Z.

There seem to be two possible explanations: The anonymous physician of Zurich may have taken an as yet unpublished treatise by Regiomontanus and included it in his larger work. But then one would expect Regiomontanus to have challenged the plagiarism; he did not shrink from intellectual combat. Or Regiomontanus may have copied the passages which interested him from the larger work, and the passages in his hand, being found among his papers after his death, may have been taken to be his. I will return to this question later.

There are three differences in detail between the two editions where they overlap. The 1548 and 1574 versions of edition R both mistakenly give the date as 1475 instead of 1472; they both give the diameter of the comet's head as 16 miles instead of 26, and they both give the comet's position relative to Spica, where the 1472 and 1474 texts cite Alramech (α-Bootis). The consistency of the 1548 and 1574 editions is not interesting except, perhaps, as an indication that the latter was taken uncritically from the earlier. The discrepancy in date may simply be a typographical error in the 1548 edition which was copied in 1574. The same is true of the sixteen miles. Simple computation with the values given in the text shows that sixteen is wrong and that twenty-six must have been meant. In both cases the number was written out in words in the fifteenth-century versions of edition Z but given as numerals in the later ones.

The change in star name is more interesting. According to Pingré, Halley computed orbital elements for the comet of 1472 based on Regiomontanus' data (my translation):

> According to [Halley's] computation, the closest Regiomontanus could have seen the comet to Spica would have been 12–13° on 13 January and this distance increased the following days. This seems to contradict what he said, that the comet had a very slow movement until it came near Spica. Spica is south of the ecliptic; but it is easy to show from the rest of Regiomontanus' narrative that he only observed the comet north of the ecliptic, that its motion after 13 January, the first day of observation by Regiomontanus, was always toward the north and so always further from Spica. Why then did Regiomontanus say "donec vicinaret Spicae?" According to Kepler [Pingré cites Hevelius here] the meaning is that the comet moved slowly as long as it was close enough to Spica for its position to be compared to the position of that star. My answer is more preremptory — — that the text of Regiomontanus is corrupt. I have before my eyes a text on comets, printed for the first time very shortly after 1472. M. l'abbé Rive, the learned bibliographer, says 1475. Regiomontanus is not named therein but his observations are detailed there in the same words we have shown above except for two differences: 1) the

observation is dated 1472, not 1475, and 2) it says "donec vicinaret Alramech" instead of Spica. The star the Arabs call Alramech is not Spica but what we call Arcturus and it is exactly true that the comet moved slowly until it was in the vicinity of Arcturus.

Comiers says that the comet began to appear 7 January and that on the 11th it was in 20 Libra, distant from Alramech by 5° in longitude and 2° in latitude, and 24 57′ from the equator. That agrees fairly well and we see Alramech in its true meaning as Arcturus and not as Spica as an ignorant copyist put it in Regiomontanus' observation. (Pingré 1783: 474–475)

Pingré evidently believes that the observation was Regiomontanus'; that it was plagiarized by the physician of Zurich without error, and that an ignorant copyist substituted Spica for Alramech some time between 1475 and 1548. I think that it is far more likely that an over-enthusiastic humanist made the change than an ignorant copyist. Spica is α-Virgmis, called Azimech in the middle ages from the Arabic simāk al-a'zal (Kunitzsch 1959: 146). Alramech is simāk al-ramih, or α-Bootes, now called Arcturus. The two stars were coupled by the Arabs as As-simākan, "the two Simāk" and the latter was often called Azimech ariamech, or Azimech for short (Kunitzsch 1959: 133). There is, then, some genuine confusion in the names of these two stars. It is likely that a good humanist would have tried to Latinize the star name, but got the wrong star in the process and did not realize from the astronomical context that Spica would not do.

Pingré states rather inconsistently that the observations in Regiomontanus' treatise were vague because his instruments were too crude for more precise measurements, then immediately quotes the observation of January 20 and remarks admiringly on its precision (Pingré 1783: 473).

Celoria (1921) uses Toscanelli's data to compute the orbital elements for this comet. He had at hand also Regiomontanus' observation of January 20, from Pingré, and an edition of the treatise quoted by Hevelius (*Cometographia*, 1668) which differs somewhat from the 1574 edition but contains the errors 1475 and Spica. (Celoria does not quote the portion containing the determination of the diameter.) Celoria's results differ quite a bit from Halley's but they do not contradict what Pingré says, quoted above. Nevertheless, Celoria makes no mention of the substitution of Spica for Alramech although he uses Pingré as a source. He does not mention the estimate of parallax and calculation of distance, nor does he question Regiomontanus' authorship of the treatise.

Zinner does. He identifies the physician of Zurich as Eberhard Schleusinger, a physician of Zurich who received his master's degree at Vienna in 1455 and was a member of Peurbach's school there. (Regiomontanus was at Vienna throughout the 1450s.) Zinner cites the peculiar use of the total sine as thirty-six and the unrefined derivation of distance as characteristics of the Vienna school which cannot be reconciled with Regiomontanus' knowledge and skill in 1472. Schleusinger and Regiomontanus knew each other and it seems plausible to Zinner that Schleusinger's treatise was among Regiomontanus' papers. When Ziegler was

in Nuremberg in 1504, he could have made extracts from it as well as from others of Regiomontanus' papers and, years later when he published it, either confused or deliberately misrepresented the authorship. On the other hand, Regiomontanus could have made the extracts himself (Zinner 1968: 209).

This seems to me such a persuasive reconstruction that I was astonished to find considerable ambiguity in both Thorndike and Hellman, the only two historians of science, as far as I know, who address themselves to this problem. In his *History of Magic and Experimental Science* (IV: 359), Thorndike identifies the physician of Zurich as Conrad Heingarter, physician and astrologer, and in a later paper (1958) gives a translation of the sections on the motion of the comet and of the tail. He says, "Part of the text of Thurecensis, including the account of the movement of the comet, was printed by Jakob Ziegler in 1548, and was utilized by Pingré in 1783". What seems extraordinary is that he does not mention anywhere that both Ziegler and Pingré as well as numerous other sixteenth to twentieth century workers, accept Regiomontanus as the author.

Hellman (1967) discusses the short treatise and accepts it as Regiomontanus' without demur, citing the 6° parallax estimate with respect to Spica as one more evidence of outstanding advance in cometary theory (Hellman 1967: 44–45). Earlier, however, she considers this treatise as Regiomontanus', but in her footnotes she acknowledges Zinner's and Thorndike's alternative views on the authorship (Hellman 1944: 82).

It is probably not possible to settle absolutely the question of authorship of this brief treatise. What seems clear is that it was published during Regiomontanus' lifetime as part of a larger work by the physician of Zurich, whoever he was; that it was published several times in the sixteenth century and subsequently under Regiomontanus' name; and that its style is different from that of the two items of unquestioned authorship. In fact, in both style and content, the larger work is very reminiscent of Vienna ms. 4756 on the comet of 1456 by Peurbach (discussed in chapter VI above). I conclude, then, that this treatise very likely was not written by Regiomontanus but by someone of Puerbach's school; that it represents an advance in observational interest and in its attempt to estimate distance and size over many earlier or even contemporary treatises; but that it does not approach either Toscanelli's or Regiomontanus' observations for care and for their quantitative nature, or Regiomontanus' problems for rigorous derivation of distance and size.

TEXT OF THE TREATISE
(edition R)

This treatise is a descriptive work which gives the path of the comet qualitatively through the constellations with indications of its speed and the direction of its tail, in general terms. Then, based on an estimate of the parallax with respect to "Spica, a star in its vicinity", of not more than six

degrees (a gross overestimate), a distance from the comet to earth of at least 8200 miles is derived. However, this computation is not performed as prescribed in the *Sixteen Problems.*

The Latin text from Hajek (1574) is given in Appendix D. My translation is as follows:

REGIOMONTANUS, ON THE COMET

On the Ides of January [January 13] 147[2], a comet was seen under Libra with the stars of Virgo. Its head moved slowly while in the vicinity of Spica, then speeded up its pace through the legs of Bootes, toward his left hand; departing from there, in one natural day [24 hours] it described a 40° portion of a great circle. When it was in the middle of Cancer, it reached its greatest distance from the ecliptic, 77°; then, between the two poles of the zodiac and the equator, it passed between the feet of Cepheus. Whence, through the breast of Cassiopea, over Andromeda's belly, after going through the length of the northern Pisces where again its motion strongly slackened, it approached the zodiac, crossing it near the middle of Aries; then, with the stars of Cetus, the setting sun hid it from us in the last days of February. By its own proper motion it described a portion of a great circle, which extended to the north contrary to the succession of the signs from Libra to Aries. It moved relatively slower at the beginning and the end; indeed in the middle of its appearance it moved most rapidly, during one day through approximately four signs, from the end of Virgo to the beginning of Gemini. According to the nature attributed to it, the motion should have continued until it had appeared back again in Libra; and perhaps its motion was thus, because when it set, its motion was still rapid. Nevertheless, on account of its relationship to the sun, it should have been visible toward the south in April, especially in northern regions, at the end of its appearance, if its motion had been regular.

Of the tail's motion

Its less mobile tail circled the stars of Gemini, continuously turned toward them, and never deviated from them through the whole time of its appearance. And so at the beginning of its appearance the tail extended to the west, because the stars of Gemini were there. At the end, when the comet was located under Aries, on account of the nearness of the sun, it appeared in the west, the tail extending toward the east, because the stars of Gemini were there. In the middle of its appearance when it passed between the two poles [the pole of the ecliptic and the north pole], it turned its tail to the south where the stars of Gemini were then. The tail extended in all directions that same night thus: immediately after sunset the tail faced the east; approaching midnight it faced south; after midnight it faced the west; before sunrise it indicated a place to the north, where the circle [*circulus*] usually stands. This tail was turned from place to place by the daily motion of the comet, that is, by the motion which depends on following the *primum mobile* and which always takes place from east to west. But furthermore, by its own motion the end of the tail was moved (however much slower than the head of the comet) always still to the west, contrary to the succession of the signs. It described a parallel from the beginning of Libra even to the middle of Taurus, passing under the feel of Ululantis, through Ursa major approaching Perseus, through the star near the Pleiades, to the tail of Aries, it entered into about the middle of Taurus. From this it is evident that the tail as well as the head traveled toward the west and never toward the east, not only by the diurnal motion but also by its own.

Of the comet's distance from earth

Those who are expert in geometry and arithmetic differ very little from that which they have from Ptolemy's tradition. He demonstrated for them in the Almagest that the inner surface of the moon's sphere is about 33 times as far from the center of the earth as that same center is

from the surface of the earth. The radius of the earth, indeed, as can be deduced, contains about 913 German miles. From this we can compute the distances of the stars from the earth as Alphraganus said with a difference of 23 [*ut dicit Alfraganus 23 differentia*]. I considered the greatest parallax of the comet's head from Spica, a star in its vicinity, reduced to account for all possible sources of error, using an instrument aligned to it: I perceived that this could not be more than six degrees. According to this parallax it follows that the body of the comet is nine times the earth's radius from the surface of the earth, which is at least 8200 miles. This places it in the upper part of the highest regions of air and not in the region of fire, supposing a ten-fold symmetry of the elements. This is just as the philosopher determined according to *On Generation* [Aristotle's *On Generation and Corruption*? I cannot find such a statement in modern editions, nor can I find any other source for this estimate of the relative thickness of the sublunar regions].

How to derive the comet's size

The size of comets can be determined from their distance to the earth and from the angular size of their visual pyramids [subtended by the comet with the eye as vertex]. For one degree on a great circle corresponds to 16 miles on the earth's circumference. Therefore if the comet were one earth radius distant from the surface of the earth and its body subtended one degree, the diameter of its body would be 16 miles. If it were twice as far, its size would be double, for as the ratio of the total sine [*sinus totius*] is (namely 60) to the distance of the star from earth, such is the ratio of the chord to the diameter of the star. The chord, I say, is that which is subtended by that portion of a great circle in the sky which such a star subtends; and such a chord is the base of the visual pyramid for this star. Therefore the base of this visual pyramid is to be multiplied by the distance of the comet from earth and the product divided by 60. This quotient is the size of the diameter of the comet. The proof of this is given elsewhere. Indeed the distance from the comet to earth is determined from the parallax of this comet (or of some part of it) with respect to some star in its vicinity.

On the comet's size

The diameter of the comet's head subtended 11 minutes of a great circle as observed with instruments. The chord of these minutes is about eleven and one-half minutes. Therefore this chord, as stated in the first part, multiplied by the distance of the comet from earth, 8200 miles, produces 94,000 miles. This is divided by the total sine, namely 3600 minutes, which yields 26 miles, which is the size of the diameter of the comet's head.The coma surrounding the head of the comet subtended about 34 minutes; therefore its diameter was about 81 miles**. Eusebius' *Ecclesiastic history*, book 3: And besides the comet is seen to burn with a deadly fire through the whole year. From Josepho: no irruption of the air can supply, from natural causes, flaming vaporous material for the comet for a period of a year; but comets come from secret causes of nature, etc. Messala the Arab [Māshā'allāh, ca. 762–815] concurs in this.

Eusebius (260–340 A.D.) wrote a voluminous church history which can be found in Migne's *Patrologia Graeca*, vols 19–24. Josepho may be Flavius Josephus (ca. 37–95 A.D.), a Jewish historian and military commander; his works are published in a Greek text by B. Niese (Berlin 1887–1895) and translated into English by W. Whiston and A. R. Shilleto (1889–1890).

COMMENTARY

This treatise is descriptive and does not satisfy some of the basic assumptions stated in the *Sixteen Problems*. The description is rather complete and detailed but there is no attempt to establish precise locations at

precise times by quantitative or instrumental measurements. The description of the comet given here is confirmed by other contemporary reports (Toscanelli, q.v.; Pingré 1783: 471–476) and by modern computations (Mucke 1972: 35). The assumption stated so often by Regiomontanus in the *Sixteen Problems*, that the comet must have no proper motion or at least only uniform motion, is clearly violated by the extremely rapid motion of this comet. The premise of problem 15, that the comet's tail must necessarily lie along the radius of the world, is also violated by the description of the tail's motion given here. We may well imagine Regiomontanus' chagrin as he observed this comet and saw that his carefully worked out theoretical treatise was not applicable to this comet, reason enough for him to withhold publication of the *Sixteen Problems*.

The distance determination in the third section of the treatise is not based on a precise measurement such as the one we have from January 20 and on the computations prescribed in the *Sixteen Problems*, but on a visual estimate of parallax with respect to a fixed star, and a very bad overestimate at that. Mucke computes that this comet approached to within 0.07 astronomical units of the earth, very close indeed for a comet. But this is more than 1644 earth radii, not nine; and its parallax would have been approximately 3″, not 6°, a value far too small to have been detected by the naked eye or with the instruments of the time. The error in the estimate may have been partly due to the comet's very rapid proper motion, although the observer was very well aware of the motion and claimed to have reduced the parallax to account for all possible sources of error. The major reason, however, may have been the author's prejudice about the "right answer".

There seems to have been no question at all that comets were below the moon, so the parallax in question would have been at least larger than the moon's parallax, which is of the order of one degree. The author of this treatise had, then, lower limit on the comet's parallax and was looking for the upper limit which, he thought, he found to be no more than 6°. The comet was, then, no closer than 8200 German miles. He implies that comets were believed to be much closer even than that.

VIII. EPILOGUE: THE SIXTEENTH CENTURY

It should not be supposed that the treatises discussed in this dissertation immediately revolutionized cometary theory. Treatises similar in style and often inferior in content to even the fourteenth century treatises continued to appear well into the sixteenth century. Some of these are discussed by Hellman (1944: 76–86) and Thorndike (IV: chap. 57). In the series of observations begun with Regiomontanus, Bernhard Walther recorded a comet on 17 January 1491 (Schöner 1544: 58 v); the style is like that of Regiomontanus' observation of 20 January 1472, with no attempt to determine parallax. But apparently no other serious astronomical work on comets was done until the 1530s, although over a dozen bright comets appeared during that interval according to European chronicles (Pingré 1783 I: 477–486).

Three spectacular comets appeared in 1531, 1532 and 1533 and aroused new interest in comets among working astronomers. As I mentioned above, it was at this time that Regiomontanus' *Sixteen Problems* was published. The most significant advance in cometary theory in this period was the observation that a comet's tail is always directed away from the sun. The people associated with this discovery are Girolamo Fracastoro, Peter Apian, Girolamo Cardano, and Johannes Vögelin; I shall deal with them in turn.

Fracastoro (ca. 1478–1553) studied at Padua and was an instructor there in logic and anatomy until 1502. After 1509 he worked at Verona. He is best known to historians of science for a long poem in Latin hexameter on syphilis (1530), which gave the name to that disease, and for his theory of contagion (Zanobio 1972: 104–107). His major astronomical work is *Homocentricorum, sive de stellis* (1538) in which he tried to replace the Ptolemaic system by a system of seventy-six homocentric spheres, the lowest of which was sublunar and was the realm of comets. He discusses the three comets of 1531–1533 which he had observed and that of 1472 about which he had read, and stated that comet's tails were always directed away from the sun: "directo semper in oppositam Soli partem" (*Homocentricorum* fol. 44 r; Hellman 1944: 88).

Apian (1495–1552) studied at Leipzig and Vienna and was a professor of mathematics at the University of Ingolstadt. He has been termed "one of the most effective popularizers of astronomical and geographical instrumentation of the sixteenth century"; he designed a quadrant and an armillary sphere

and in 1534 published a table of sines computed for every minute. His *Cosmographia* (1524) was a work in cartography based on Ptolemy (Kish 1970: 178–179).

Apian's researches on comets include tracts on the comets of 1531 and 1532 and are described in his *Astronomicum Caesareum* (1540). In it he notes the positions and motions of the comets of 1531, 1532, 1533, 1538, and 1539 and states that the tail always points away from the sun. His tracts, published in 1532, were illustrated with diagrams which showed the axes of the comet's tails passing through the sun, but did not contain the general statement that this is always true. Apian was generally credited with the discovery by his contemporaries, though Fracastoro's *Homocentricorum* was published two years before Apian's *Astronomicum*. Apian was familiar with Regiomontanus' work on parallax and used the method for determining terrestrial distances, but he seems not to have applied it to determining cometary distances from the earth. He accepted the traditional sublunary location of comets but made cometary observations in the same way that he made other astronomical observations. He noted that comets disappear in the immediate vicinity of the sun and reappear later (Hellman 1944: 88–90).

Cardano (1501–1576) was educated at Pavia and Padua and practiced and taught medicine at Milan, Edinburgh, Pavia, and Bologna. He is chiefly known for his mathematical work on third-degree equations and on probability. In 1570 he was imprisoned by the Inquisition for having cast Christ's horoscope and asserting that the events of His life had been determined by the stars; he later recanted but had to give up teaching (Gliozzi 1971: 64–67). Cardano's cometary theories are expounded in *De subtilitate* (1550) and *De rerum varietate* (1557). He believes that comet's tails are always directed away from the sun because, he says, the sun's rays shine through the body of the comet, which is a kind of crystalline globe, and form the tail through a kind of optical effect.

Cardano is most important here, however, because he openly contests the Aristotelian doctrine on the location of comets in the upper atmosphere. His conviction about the supralunar position of comets is based on the fact that the comet of 1532 moved slower than the moon, therefore must have been farther away. This is an extension of the Aristotelian claim that distance is proportional to period (*De caelo* II, 10). A further argument he advances is that terrestrial vapors could not rise so high nor burn so long as would be required to account for the actual appearances of comets. But, he says, it would be easy to decide by means of parallax measurements: if a comet has greater parallax than the moon, it is below it; if less, then above:

> Sed deprachendere an Cometes in elementorum regione sit, an in coelo fiat: facile est admodum. Nam si maiorem ha eat diuersitatem, quam Luna, in elementorum esse regione necesse est: sed si minorem, in coelo fiet procul dubio. (*De subtilitate* in Cardano's *Opera omnia*, Lyons 1663, III: 420)

Nevertheless, he did not perform the necessary observations or computations (Hellman 1944: 91–96).

Johannes Vögelin was professor of mathematics at Vienna and wrote *Significatio cometae qui anno 1532 apparuit* (1533) (Hajek 1574: 150–167). I have published elsewhere (Jervis 1980) a detailed analysis of this very interesting tract (it is strictly speaking beyond the scope of this work) and I will only summarize it briefly here. Vögelin uses Regiomontanus' recently published *Sixteen Problems* to determine the comet's parallax and distance from earth. Taking two altitude and azimuth observations 42 minutes apart and rigorously following the method of Regiomontanus' problem 2, he derives parallaxes for the two observations of 35°31′1″ and 34°58′5″, astonishingly large values; these give him a distance of 1535 German miles from the comet to the center of the earth, far closer than the estimates by Peurbach and the physician of Zurich discussed above.

The comet of 1532 in fact approached to within 0.67 astronomical units of the earth (Mucke 1972: 38), which is over 60 million miles, and would have had a parallax of a fraction of a minute of arc, far below the limits of observation. Distortions due to refraction, observer's errors, and especially the comet's own motion completely swamp the phenomenon being measured. Vögelin's treatise is a clear case of an elegant and correct theoretical method being correctly applied to a natural phenomenon, being completely inadequate to the task, and being unrecognized as such.

Copernicus observed the comet of 1533 and wrote a brief treatise on it (published by Curtze 1878: 41–43), but he did not consider comets to be celestial phenomena. There is one reference to comets in his major work *De revolutionibus* (1543) in book I, chapter 8, where he uses the motion of comets to demonstrate that the upper regions of the air take part in the daily celestial rotation. Since *De revolutionibus* essentially follows the *Almagest* closely in its arrangement, it is not surprising that Copernicus excludes comets as had Ptolemy.

The atmospheric location of comets was being challenged on other grounds. Jean Pena, royal mathematician at Paris, in 1557 reasoned from his optical theory that the air must extend homogeneously throughout the heavens, that refraction in the Aristotelian spheres would make astronomical observations impossible, and that some comets at least were far above the moon (Thorndike VI: 71).

Except for Vögelin's tract, I have not studied at first hand the many cometary treatises of the mid-sixteenth century. Hellman (1944) describes many of them, working from secondary sources herself. These treatises display wide interest in comets and increasing care in observational method, but there is no further advance in theory until the 1570s with the work of Tycho Brahe (1546–1601) on the nova of 1572 and the comet of 1577.

Comets and novas presented similar philosophical problems to astrono-

mers. New stars were simply not permissible in perfect and unchanging heavens. Many astronomers made parallax measurements of the nova of 1572; some concluded that it was not celestial, despite the lack of perceptible parallax, and some in fact found a large parallax (Hellman 1944: 114–117). Tycho Brahe used the method of Regiomontanus' problem nine, which measures the comet's distance from two nearby known stars and finds the apparent position by triangulation. This was the best available method, eliminating refractive problems and minimizing instrumental error and errors in positions of stars. Tycho found no parallax and concluded absolutely that the nova was in the region of the fixed stars and was in fact a star, not a comet or meteor, because the latter are sublunar. The nova of 1572 is the subject of book I of Tycho's *Astronomiae instauratae progymnasmata*, completed after book II on the comet of 1577, found in volume three of his *Opera omnia* (J. L. E. Dreyer, ed.).

Brahe's work on the comet of 1577 was reported first briefly in a German tract (1578) for popular consumption, then at length in book II of the *Progymnasmata*, entitled *De mundi aetherei recentioribus phaenominis* (1588). Both of these cometary treatises are in volume four of the *Opera omnia*. All of his observations are in the form of angular distances from fixed stars, which he then reduces to positions in right ascension and declination and in longitude and latitude. He finds no parallax and concludes that, like the nova, the comet is far beyond the moon. He uses several different methods for determining the parallax, including a comparison of his measurements made at Hveen with those made by Hagecius (Hajek) at Prague. He used Regiomontanus' method with two altitudes and azimuths but commented on the inadequacies of the method (Brahe 1588: 126; Dreyer 1890: 166 says p. 156):

> Verum, quia Regiomontanus, in hac Pragmatia praesupposuit, Cometam non moveri nisi motu primi mobilis, Hic vero (de quo nunc tractamus) & omnes fere alij, sensibilem cursum proprium, etiam vel tantillo interiecto temporis spatio, obtineant, res haec maiori ante omnia indigebit limitatione, quam Regiomontanus, sive de industria, sive quod eam in magnis Parallaxibus, quas Cometis inesse praesupposuit, minus movere dubij iudicarit, non sine despendio veritatis quam inquirere proposuit, neglexisse videtur.

And, somewhat later (Brahe 1588: 134):

> Quare iam satis superque, non solum proprijs Rationibus, quae in Praxin commodius & rectius deduci poterant, set etiam Regiomontani Methodo, utquamvis minus negocio huic competenti, evidenter confirmavimus, Cometam hunc plane Aethereum extitisse, & omnem sensibilem Parallaxeos quantitatem respuisse.

Or, in my translation (with G. Toomer's assistance):

> But since Regiomontanus in this treatise assumed that a comet has no motion except that of the *primum mobile* (whereas this comet with which we are now dealing and almost all others have a proper motion which is sensible even over a very small interval of time), this matter will first of all require closer determination. Regiomontanus, with considerable detriment to that truth which was the goal he had set himself, appears to have neglected this, either on purpose,

or because he judged that there was less doubt about the matter given the large parallaxes which he assumed comets have. [...] Wherefore, we have evidently in this treatise more than sufficiently confirmed, not only by proper calculations which could be appropriately and fittingly derived, but even by Regiomontanus' method, however little value this has, that this comet clearly is located in the Aether, and rejects any perceptible amount of parallax.

Chapter 8 of this book contains the first description of his system of the universe, later known as the Tychonic system, in which the sun, moon, and fixed stars revolve around the earth, while the other planets revolve around the sun. The comet was thought to have an orbit around the sun outside that of Venus. In this system some of the orbits intersect, which is incompatible with solid crystalline spheres. There was, however, continuing discussion of the nature of the spheres; Donahue (1975: 244–275) discusses theories of solid or fluid spheres in the sixteenth and early seventeenth centuries.

After 1577, astronomers were increasingly concerned with determining cometary orbits, considering comets to be planetary objects of a special kind which, though they might be transitory, were expected to behave during their brief life span according to rules similar to those which govern planetary motion. Brahe, as we have just seen, placed the comet of 1577 in a circular orbit just outside that of Venus. But his interest in comets was primarily cosmological and he accepted the orbital computations of Michael Maestlin (1550–1631), published in *Observatio et demonstratio cometae aetherae qui anno 1577 et 1578 constitutus in sphaera Veneris apparuit* ... (1578).

Maestlin's observations of both the nova of 1472 and the comet of 1577 were made simply by holding a thread up to locate the body on straight lines between nearby known stars (Maestlin 1578: chap. 5). Maestlin concluded that both the nova and the comet were celestial because of their lack of daily parallax, and proceeded painstakingly to work out the orbital parameters for the comet. He discovered that it followed a great-circle path very steeply inclined to the ecliptic and that it had great variation in speed. All his attempts to reconcile these data with a Ptolemaic scheme failed and he was driven reluctantly, he said, to adopt the Copernican hypothesis as the only possible way of saving the appearances of this comet. Having tried all the planetary spheres, he settled on the sphere of Venus as the only one whose dimensions were compatible with his observations, and he derived the dimensions of the model for this comet. He saw this as a mathematical construction, but apparently was not fully aware of the complete geometrical equivalence of the Ptolemaic and Copernican systems. He did not argue for the physical reality of his model; the comet's retrograde motion would have been hard to explain if it had actually been carried around by the sphere of Venus (Westman 1971: 44–66).

Maestlin passed his Copernicanism on to his pupil, Johannes Kepler (1571–1630). But Kepler departed radically from his teacher's explanation of comets. He believed that comets could not follow circular paths because then they would inevitably return. Their transience was for him an argument for a

rectilinear path, "because it suits the nature of things" (Kepler *Gesammelte Werke* II: 287), whose apparent curvature was caused by the motion of the earth in its orbit. Kepler's major work on comets was *De cometis libelli tres* (1619; *Gesammelte Werke* VIII) which has a quotation from Seneca on the title page (cited as VI, 26; in the Loeb Library edition it is in VII, 25):

> Some day there will be a man who will show in what regions comets have their orbit, why they travel so remote from other celestial bodies, how large they are and what sort they are. Let us be satisfied with what we have found out, and let our descendants also contribute something to the truth. (Quoted above in chapter I.)

I will not repeat Kepler's argument here. Ruffner (1966: 94–118) traces Kepler's views on comets in some detail. The important result for cometary theory was that comets were once again removed from planetary astronomy where they had been for such a very short time, and again were considered as special kinds of bodies, now celestial to be sure, but bodies which were governed by different laws than were the planets. It remained for Edmond Halley and then for Isaac Newton, late in the seventeenth century, to integrate comets into a dynamic planetary system.

SUMMARY AND CONCLUSIONS

In this work I have examined fifteenth-century cometary research in the context of cometary theory from antiquity to the end of the sixteenth century. I began by describing the classical views of comets, particularly those of Aristotle and Seneca. Aristotle, who was to dominate well into the sixteenth century, held that comets were formed from terrestrial exhalations which rose to the higher regions of the atmosphere and were ignited under special conditions; thus they were meteorological phenomena not to be considered among celestial objects as part of the domain of astronomy. The cometary theory was completely integrated into Aristotle's cosmological scheme, with the result that deviation from this portion was taken to be an attack on the whole. Seneca's was a more open-minded view, acknowledging that much was unknown but suggesting that comets might be planetary bodies of a special kind which were visible to us only in the lowest portions of their orbits.

A brief survey of medieval writers on comets has shown how completely the Aristotelian explanation dominated the thinking at that time. It was not until the comets of 1299 and 1301 that we find cometary treatises, by Peter of Limoges, which contain quantitative positional data obtained with observational instruments. There are other examples of good observational data for comets, but still couched in descriptive language within an astrological context, and usually of a single position only.

The manuscript by Paolo Toscanelli contains the earliest systematic cometary observations, day-by-day positions plotted on star maps, treating comets as if they were celestial bodies. Unfortunately I did not find any discussion by Toscanelli of his cometary theory, of what he supposed their composition or distance from earth to be.

The first attempt to find the distance of comets from the earth was by Peurbach in 1456. His approximate estimate of parallax proved to him that the comet of 1456 was at least a thousand German miles away. Peurbach seems to have been trying to establish the lower limit on cometary distance, the upper limit being understood to be the lunar sphere.

This also seems to have been Regiomontanus' intent when he developed the mathematical techniques for determining distance from daily parallax. It is important to emphasize again that the values of parallax which Peurbach

and Regiomontanus were looking for were larger than 1° (the parallax of the moon) and probably of the order of 5° or 6°. They were looking for the upper limit of parallax, that is, the lower limit of distance from the earth. Remembering the Aristotelian view that comets were in the upper region of the air, below the region of fire, we may well wonder if they were in fact trying to determine the thickness of the atmosphere by means of these cometary measurements. This motive, if indeed it was their motive, is nowhere explicitly stated.

We have seen a few sixteenth-century efforts to apply Regiomontanus, but distortions due to atmospheric refraction, observational error, and the comet's own motion overwhelmed the very small effect in question. In fact the very best naked-eye observations, those by Tycho Brahe, could only determine that there was no discernible parallax.

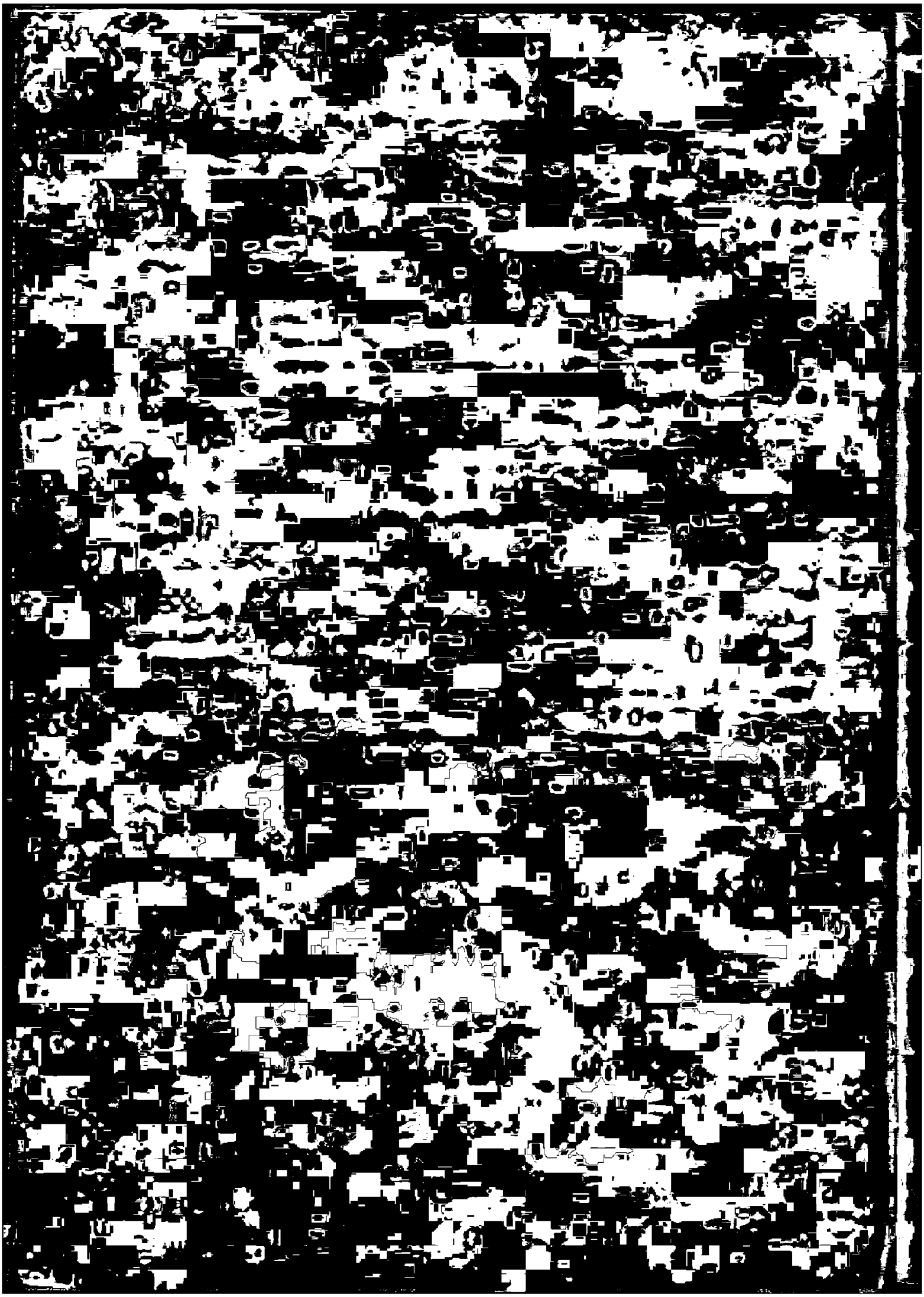
We have also seen how interest in the direction of the comet's tail, which was at first motivated by astrological considerations, the tail being a kind of divine finger pointing to the region of the comet's influence, resulted in the generalization that the tail was always directed away from the sun, but not until the 1530s.

The other advance in cometary theory in the sixteenth century was in the attempt to compute cometary orbits. This followed naturally from the developing belief in comets as a kind of planetary body, a belief which was perhaps implicit in Toscanelli's series of observations and in Peurbach's and Regiomontanus' inclusion of cometary observations among other planetary observations. The integration of comets into the scope of astronomical research is probably the greatest contribution of the people I have discussed here. I would like to think that they did this consciously and deliberately, in an effort to decide experimentally and mathematically between conflicting hypotheses about the nature and location of comets. I have found no evidence either to corroborate or to disprove this.

Appendix A.

JACOBUS ANGELUS: "TRACTATUS DE COMETIS"

We reproduce here, with the kind permission of the Jagellonian Library, the incunabulum edition of this treatise, printed at Memmingen (not dated, but assigned a date 1480 by Houzeau 5534; 1490 by Thorndike IV: 80. and Collard 1935: 83).



Tractatus de cometis.

¶ Hec ſunt capitula in ſequentē libellum.

¶ Capitulū primū recitans opiniones antiquoꝝ de eſſentia comete et eius cauſis.

¶ Capitulum ſcōm in quo manifeſtant cauſe impreſſionum in aere apparentiū generales.

¶ Capitulū tertiū in quo oſtendet quid eſt cometa ſecundū Ariſtotilem et alios pōes ponentium eam eſſe de natura elementari. Et eſt via que cōmuniter tenet.

¶ Capitulum quartum de diuerſitate cometarum.

¶ Capitulum quintuꝫ de ſignificatione cometarum

¶ Capitulū ſextū de diſpoſitiōe comete et forma ei⁹ coloꝛe: quia apparuit his diebus.

¶ Capitulum ſeptimū deſignificatione comete preſentis anni naturaliter intro ducte.

¶ Capitulum octauum de ſignificatione huius comete ſcōm viam aſtrologorum.

¶ Capitulum nonum in quo ponunt exempla cronicis antiquoꝝ et modernoꝝ ſuper figuratione cometarum

¶ Capituluꝫ vltimū in quo oſtendit q̄ fideles catholici non debent aduertere nec illam nec aliarum ſtellariū ſignificationes:

¶ Incipit tractatus de ap
paritione comete stelle.

Vlti mirati fuerunt de apparitione comete stelle que apparuit his diebꝫ et non sine causa tamē quia raro vident tales stellas tamen quia fuit valde notabil in ipsa et ꝙntum ad radium supra se valde notabiliter elongatum tamē quia etiam antiqui philosophi de ea multas et varias opiniões dispuauerūt generales aut eius significatōnes ab Aristotile et aliis antiquis philosophis et modus generationis et eius cause sunt sepe et sepius satis lucide declarate ¶ Lectio tñ lecta placuit et repetita placebit. qua ꝓpter cum auxilio omnipotentis dei incendo de cometa et modo generatōnis eiusdē causis aliquid in psenti tractatu sepe ab aliis dicta de eorūdem replicare: ad laudem precipue dñi nostri ihesu christi et gloriosissime semp virginis marie et ob honorem et vtilitatem illustris principis dñi mei ducis leopoldi ducis austrie stirie ꝛc. Ac etiā ob reuerentiā et vtilitatem dominorū meorum magistrō ciuium atq; cōsulem ciuitatis vimensis et ob totius cōmunitatis pfectuꝫ ciuitatis predicte, his enim post deum ꝓpter impensa mihi beneficia ꝙ plurima pre cunctis plus obligor ad seruiendum. ¶ Presentē igitur tractatū in capitula distinguam diuersa quorū in legendo numerus cum suis titulis apparebit.

¶ Capitulum primū recitans opiniones antiquorū de essentia comete et eius causis

Ꝛcerunt quidē igitur de antiquis phis de quorum numero fuit Anaxagoras et Democritꝰ etiam quidam qui vocabat Appolonius vt refert Seneca in libro suo de naturalibus questionibꝰ qp

a ij

cometa esset quedam cõiunctio pluriũ stellarũ que vo-
centur planete. Cum enim plures planete coniũgũt
per eorum iuxta positionem in longum quantũ ad ap-
parentiã nri aspect⁹ apparet vna stella lõga comata q̃
cometa nominatur ista fuit illoꝝ philosophoꝝ via et
hãc etiã recitat Aristotiles pmo metho. in capitulo de
cometis ex quo patet q̃ isti philosophi ponebãt come-
tam esse de natura celesti. ¶Quidã autẽ italicorũ phi-
losophorum pictagorice dixerũt. q̃ stella comata non
est nisi vna stella et non simul multe. vt dixerunt p̃cedẽ
tes nec voluerunt per hoc q̃ semp vna et eadem nunc
eo esset cometa sed de pluribus quoꝝ posset esse come
ta successius et sẽm illos aliquid de planetis q̃ñq̃ ap-
paret. Q̃ñq̃ cometa nunc vnus nunc alius ex isti ſalua
bant caudam seu comã propter dinatizationem radioꝝ
luminis in vapore spissio interposito inter planetam ⁊
nostrum aspectum tamẽ quia mercurius raro apparet
maxime mercuriũ fecerunt cometam esse de illa etiaꝫ lo
quitur Aristotiles. ¶Fuerunt et alij antiq̃ sicut Ypo-
cras et socij sui Clichius et Paulus qui ꝯcordant cuꝫ pi
tagoricis quantũ ad essentiã comete quia dixerũt etiã
q̃ cometa sit vna de stellis erraticis et planetis. Sz
caudam dixerunt fieri per reflectionem luminis ab ae-
re quodam distante spisso et humido versus astrũ ⁊ Re
cte sicut speculum reddit luminosum radium de se p̃ re-
flectionẽ ad aerem sibi continuũ. Ex quo apparet radi⁹
quidem luminis seu vna pars aeris iuxta stellam mag
illuminata que dicit coma ⁊ ista opinio quantũ de mo
do generationis in precedente non multũ differt vt pa
tet intuenti. Isti etiam dixerunt cometam esse de natu
ra celesti. ¶Fuerunt et alij vt Johãnes damascenus et
sequentes eius qui dixerunt q̃ cometa est vna stella nõ
de antiquis aliqua neq̃ de fixis neq̃ planetis sed vna

stella de nouo a deo creata que aliquando incipit ap-
parere et iussu dei per tempus paruū desinit esse. ¶ Huic
etiam opinio Senece q cometa esset stella quedam n
elementalis nature que qñq apparet qñq recedit eq
q extinguatur Et quia ioem valde attentice loquitur
ioco verba sua ad literam hic ponam. Dicat enim con.
eas esse sidus inter opa nature concretū cuius licet na-
tura ignota tamē ipsum non esse ignem subtilissimū sic
probat quecumq aer creat biennio sine quo igitur co-
meta potest in aere diu permanere cum aer per se non
diu maneat nascuntur hec in re fugatiua atq mobili si
erig non potest vt ignis vagus in corpore incerto sede
at et tam pertinaciter inhereat. ¶ Fuerūt etiam quidā
modernī doctores vt recitat Albert⁹ magnus Qui co-
metam dixerunt fieri ex flectione luminis alicuius pla-
nete in terminū vel cōnexum aeris contingit scauo ig-
nis. Lumen enim in isto loco extensum et ex quadā re-
flexione illius luminis ibi existentis videt coma ꝯgrega
ta ex radijs quibusdam luminosis et obscuris simul mix
tis. ¶ Iste positio me videre haberet dicere cometā es-
se ymaginē alicuius planete vel stelle in quodā corpo
re polito qđ esset aer vel aliquid elementare speculum
in quo appareret sicut stella et postea reflexi quam lu-
minosi radij facerent comā. ¶ Iste sunt opiniones illo
rum de essentia comete et suis causis. Et aliquas illa-
rum recitat phus prio methe. et eas improbat. Vnde oppo
prima secta et tertia per hoc nō possunt stare quia pla
nete latitudinem zodyaci non exeunt sed plures come-
te vise sunt extra zodyacū vt sepe patuit qua ꝯpter nec
aggregatio planetarum nec vnus ex planetis nec eorū
ymagines tanquam in speculo reflexe poterunt dici co
mete. ¶ Tertia comete vise sunt sicut sol vt dicit Sene-
ca q tempore Demetrij regis sue modicū ante Achayci

bellum vsque fuit cometa non minor sole. ¶ Item vt re
citat Aristoteles et etiam Seneca q regnante in gre
cia Artexilo vel Astio principe apparuit cometa qui fi
naliter caudam suam fudit vsque in tertiam partem ce
li. ¶ Quomodo ex quantitate. ex colore. ex situ sub celo
ex eorum desinitione manifesta oculis ex longitudine t
varietate eande ex pluralitate cometarum simul con
cludimus falsitas opinionum omnium predictarum.

¶ Capitulum secundum in quo
manifestatur cause impressionū
in alio apparentiū generales

Mto methoroloyce impressiones que in alto
apparent cuiuscunque etiam genel sint ma
teriam sue generationis et subiectum sumunt
ab his fumis qui ab elementis inferioribus elevant istō
patet ex processu philosophi primo. secundo. et tertio.
methororum. ¶ Pro quo notandum q virtute calefa
ctiua solis ac etiam aliarum planetarum qui non nun
quam solem iuuant tanquam causa effectiua et princi
paliter actiua vapores tam a terra q̄ ab aqua per vi
am resolutionis et subtiliationis partium vtriusq elē
menti elevantur vno tempore plus q̄ in alio secundus
q terra fuerit magis sicca vel humectata et secundus
q resoluta virtus in solo fuerit debilior vel fortior nam
in solis calefactione vapores citius q̄ elementur resol
uuntur in aerem vel in ignē nec elevatio multa fit tpe
frigidissimo tempora enim inter media vt est ver et au
umpnus cōmuniter humidiora sunt et resoluta virtus
magis temperata vnde in istis temporibus ceteris tē
poribus maior est vapor elevatio q̄ in hyeme aut esta
te. ¶ Pro quo vltarius est notandum q si talis vapor
elevetur ab aqua et partibus aqueis magis tunc attri
net aque et eius nature erit scilicet frigidus et humidū

Si autem eleuetur a terra et partibus terreis tunc ar
ret magis terre et erit eius nature ſcilicet frigidus et
ſiccus et hoc eſt verum eſſentialiter. Eſt enim vapor ei⁹
dem nature ſpecifice in iſtis omogenijs cuius nature
et eſſentie eſt iſtud a quo eſt reſolutus
¶ Viterius notandum eſt q vterq; vapor accidentar
liter eſt calidus propter impreſſiones agentis qđ eſt ca
lor ſolis ita q vapor aque eſt calidus humidus. vapor
terre eſt calidus ſiccus. ¶ Viterius nota. Si in vapore
terre caliditas numū excederet ab humido potius ge
neraretur ignis q̄ aliquid aliud Et ſi in vapore aque ca
liditas que nunquam vinceret vapor iſte mutaretur in
aerem citius q̄ in aliquid aliud. ¶ Propterea viterius
nota q quando ſunt tales fumi et vapores aquei aut
terrei ex quibus impreſſiones in alto apparentes debet
generari. oportet quod accidētalis caliditas ſit in eis
cuius moderamine tali ſub quo poſſint ſub ſuis formis in
eſſe remanere alias nulla generaretur ex eis in alto im
preſſio ve patet et dicta. ¶ Viterius nota q ex vapo
re calido et humido modo predicto in altum leuato vſq;
ad mediam regionem aeris quia vltra eam transi
re non poteſt generant omnes impreſſiones metho
roloice aquee nature ſicut eſt pluuia nix grādo roſ pru
ina et huiuſmodi etiam in tali vapore fiunt reflexiones
radiorum ſolis vel aliorum luminarium vnde tunc ap
parent figure et calores diuerſi in media aeris regione
ſecundū q tales vapores fiunt nigri dēſi albi rari groſ
ſi ſubtiles et iam in forma gutturalium parvarum pro
ducti. Hee igitur impreſſiones aquee generantur prop
ter frigiditatē medie regionis aeris que eſt valde frigi
da et ſic habemus ſignū de gutturalis in lapidibus bulē
tium ollarum et tempore remiſſionis frigiditatis poſt
quam magnum frigus apparuit inde nunc in lapid⁹

mutorum apparet guttule sicut sudor defluentis aque de istis impressionibus aqueis et de tali vapore quia non hic fecimus nobis in presenti materia volo amplius pertractare. Sed de vapore terreo seu ex terrestribus partibus elevato qui est calidus et siccus qui secundum nobis in presenti materia erit quodammodo intentio principalis et istum vaporem volo amplius exalationem nominare. ¶ Pro quo sciendum quod ista exalatio quandoque est multum grossa minus calida magis terrestris et minus levis. Aliquando est magis subtilis magis calida et sicca et magis levis. ¶ Prima exalatio secundum ventos et ex ea fiunt venti. unde dicitur communiter quod materia ventorum est exalatio calida et sicca intelligo de illa prima exalatione. Et qualiter fiunt venti videndum est secundo methororum. ¶ Altera autem exalatio que est magis calida et subtilis que habet secundum impressionibus ignitis etiam posterius secundum duos modos considerari quia quedam talis est magis calida et ista potest pertransire spacium medie regionis aeris et venire usque ad istum hoc est ad supremi regionem aeris. ¶ Altera autem exalatio est minus calida et nequit tantum resistere vel penetrare possit frigidi regionem. Adhuc iste exalationes due differunt in modo subtilitatis et grossitie propter grossitiem et humiditatem primam te quod ista que ad istum quietis frequenter est de humiditate magis viscosa et in partibus magis aggregata et tenacitatis et maioris grossitatis eo quod quantitas muscarum ad actionem et resistentiam sed que non transit ad supremam regionem aeris ista est minus viscosa et magis rara et subtilis talis exalatio quod non sic penetrat medium regionem aeris est materia multarum impressionum ignitarum que in aere apparet secundum diversas grossitates colores et figuras differentes et hoc magis patet quia etiam apparere possunt in estu ignes et flamme aere transeuntes tum magis manifesta fiunt in

media regione et qualiter fiant et quō et q̄lis situs illō apparet primo methoroꝝ quia aliquādo vident ignes vt columpne aliquādo vt lancee: aliquādo vt candela aliquando vt draco volans aliquando vt stella volās aliquādo vt globus aliquādo vt duplex candela aliq̄n vt capre saltates aliq̄n a sub ascendens aliq̄n a sub descendens et a sub est ignis sicut duplex flāma candele. quarū vna supra alias appareret ꝓa exponit Albertus ¶ Vel a sub pōt esse nomē generis ad plures ignes in alto ita q̄ traps et globus in huiusmōi dicunt a sub. Dim igit illoꝝ igneū materiale causa est exalatio calida et sicca sursū elevata et ꝓpter circūstans frigus intra se ꝯtracta et vnita et fortificata in caliditate tanta que iussit eit in subiecto ꝓprio ignem ꝓducere et per ꝓsequens flāma et q̄lem tunc ista materia in aere sic sparsa habuerit modū substātie quādmodō est in subtilitate. et grossitie et q̄lem figuram et situ scōm ꝓtes et multitudinem et magnitudinē talem ostendit inflāmataꝝ figurā. Determinate eni de his determinare esset nimis lōguꝝ cuz non sit intentio principalis de istis nūc memorare. Et nō est bonū signū quādo tales ignes multū apparēt quia significant q̄ aer non sit pur⁹ sed malis fumis interdum venenosis ꝑmixtus qui et pascua corūpunt et pestē pecorum procreant et humidū et pruinā futuroꝝ comitas. ¶ Sed quereret aliquis quare potius exalatio terrea est inflammabilis et apta istis impressionibus quā vapor aqueus. ¶ Respondet Albertus q̄ hoc est propter quatuor causas. ¶ Prima quia exalatio est magis spissa et grossa et densa et in partibus magis vnita vt de calore infimissus terrestris postquam intrauit magis aggregatur et potius retinetur q̄z in humido aqueo ¶ Secunda causa quia omne solidum durabilius est q̄z rarum et per consequens maioris resistentie erga suum

contrarium vnde tunc ꝑ̃ altius ascendere per suũ cõ
trarium ꝙ de vapore aqueo vapore et in partib⁹ dissolu
to non est possibile. ¶ Tertia causa est similitudo. magis
enim est conuenientia et propinquitas ad ignis gene
rationem quando materia est calida et ficca ꝯ̃ ipsa
fuerit calida humida. ¶ Quarta causa humidum aque
um non posset sustinere tantum caloris gradum quin ci
tius mutaretur in aerez ꝯ̃ potest exalatio calida et sic
ca. ¶ Vnde exalatio calida et ficca est aptior pro istis
ignibus ꝯ̃ aliquis alius vapor. ¶ Pro quo nota ꝙ tas
les exalationes multum habent inter se differentiam.
quantum admodũ substantie earum quia quedaz sunt
grossiores et densiores et viscosiores in partibus multũ
vnte quedam autem non habent se sic vnde ille exala
tiones de primo modo inflammate diutius durãt et il
le tactores citius desperent vnde in suprema regione ae
ris apparent quandoqz flãme que ceruissime cranescũt.
Aliquando apparent flãme diu durantes vt patebit.

¶ Capitulũ tertiũ in quo ostenderur quid est
cometa secõm Aristotilẽ et alios phos ponẽ
tiam eam esse de natura elementari. Et est
via que communiter tenetur.

X dictis philosophi metheororū in capitulo de
cometis et etiam ex dictis aliorū elicitur q̄ co
meta nihil aliud est q̄ vapor terreus calidus et
sicc⁹ qui dicit exalatio grossus in modo sue substātie vi
scosus et magnus in ordine ad exalatōnes aliorū ignēs
suus partes multum sibi comacens in inferiori pte est⁹
aggregatus paulatim Ascendens ad superiorem par-
tem eiusdem in concauo spere ignis per ignem diffusus
et accēsus in forma stelle habentis caudam. ¶ Dicitur
q̄ sit vapor terreus propter causam superius dictam in

capitulo precedenti quia est vna impressio ignita et cō
cales fundantur in exalatione calida et sicca vt dictum
est. Et dicitur grossus propter causam superius dictam
quia si esset subtilis cito euanesceret et propterea pon
itur q̄ sit viscosus: viscositas autem magis fundatur in
humiditate aerea inflammabili et dicitur magnus vel
nullus quia ignis in parua materia non posset tam diu
durare et dicitur cuius partes sibi multum contacte
propter fortem resistentiam actientium igne ne totus
simul consumatur quasi essent partes distantes mul-
tum vel cito euanesceret aut vna lux inferna stelle nō
appareret et dicitur in inferiori parte ejus aggrega-
tus paulatim ascendens. ¶ Pro quo est notandum q̄
in parte illa que Ascendit ad concauum ignis appa-
ret flamma et nisi continuum et successiuum fomentum
a thesauro inferiori materie reciperet: ista flamma ci
to diffugeret sicut apparet de candela ardente in qua p
tes cere per ignem diffuse ardent continue et flam mēt
et lucent partes autem cere grosse non lucent sed flam
me cōtinuum fomentū prebent et q̄ diu durat cera tā
diu flamma candele et sicut cera desinit ita flamma
desinit. Ita consimiliter q̄ diu fomentum flamme a pr
te inferiori estuc proueniet de thesauro collecte materie
tam diu apparet flamma et stella et sicut illa tota est
consumpta tunc desinit esse flamma et stella caudata
¶ Imaginandum est q̄ inferiori materia aggregata et
iam accepiat per aliquod tempus continuum fomentū
per ascensum nouatum exalationum. unde per talem
successionem potemus saluare flamme istius generati
onē etiā oportet nos dicere quod talis exalatio sit ta
lis modi substātie quod in vna parte accensa ignis vl
tra procedere nequeat nisi quantum ad diffusam pri
mā inflāmationem sic imaginamur de cādela unde alias

ractio Sensus precarto multum ꝓcluderet. Cetera que ponit ſatis patet. ¶ Et quo patet quid ſit ſua cauda vel luminoſitas illa a tali ſtella ita in longū protenſa quia non eſt aliud niſi quia quedā partes ſubtiliores ab igne reſolutione diffuſe nunc ad vnam ꝑtem nunc ad aliam ſimiliter inflāmatur flamma tenui ad modū nubis alte et verſus quam ꝑtem ille ſubtiles et tenues exhalationes ſe diffundunt in illa parte inflammāt et verſus illam partem apparet cauda et deformitas illa ꝙ partium in groſſitie et ſubtilitate erit cauſa diuerſitatis et̄ inſitu et poſitione. ¶ Et adſaluandū appārētias in cauda oportet dicere ꝙ tales fumi tenues a principali flāma procedant ſe cōtinue dilatando quia cauda ꝑtis ſentia comete fuit figure piramidalis cuius com̄ fuit in eſſentia luminis comete et baſis eius in longū diſtans Vnde credo tamē ꝙ ſatis difficile eſt ſaluare iſtam regularitatē tōti caude que ita per rectas lineas ꝓcluſa ē ſicut viſio apparuit eius figura notabil regulata et pulchra valde niſi per iſtum modū vt dixi ponēdo ſemꝑ ꝙ cauda ſit materialis res Similiter quedam flāma vt dicit Albertus niſi vellemus dicere ꝙ apparet ſic ꝓpter in corporationē luminis in materia denſa alba et ſpiſſa ſicut de nubibus videmus aliquando nigras aliquādo albam aliquando rubeas. ¶ Modus igit̄ generationis comete dictus eſt de impreſſione phi in primo metheorum ſic ſatis patet ibidem et ſue rationes et huic concordat Albert⁹ in libro ſuo metheorū huic concordat Conſtantinus phus et Auicenna eādem tenet viā qui dicit ꝙ ſtella comata fit ex fumo ſpiſſo et ignito qui circo non ꝓcertitur ſed aliq̄ diu circumſoluit cum igne.

¶ Agaſel autē in phiſica ſua ſic dicit de cometa ſi ignis ꝓualuit ſup fumū elevatum purgabit eum a caligine et tunc totus fumus ꝓcertitur in ignē ſed quia ſpiſſus eſt

ignis quidez. Sed quia non est talis qui cito cõuertat remanebit aliq̃ diu et videbit stella comata et talis revolvit cum celo ꝓpterea quia ignis cõtiguꝰ est cõcauitatiꝰ celi ꝙ circulariꝫ movet vt ignis per cõsortiũ revolvit cum celo. Et ꝙ cõsequẽs candata stella que splẽdet in igne. ¶ Et sũdis Agasel materia talis vaporis sit revoluta cum celo soles triplicã ꝓsistentia apparere. ¶ Aliq̃n enim est grossa magis et spissa a pauca ꝛ tunc ignita apparet vt carbo incensus. ¶ Aliq̃n est magis alba et clara et tunc eꝰ flãma est clara et incensa. ¶ Aliquando talis materia est ita spissa et grossa terrestris ꝙ ignis in ea extinguit et suffocatur et remanet substãtia quedã fumosa spissa bene nigra et tunc aspicientes credunt celum esse ꝓforatum et vident formã nigram ¶ Alpetragius in astronomia sua per hoc ꝓbat ignem circulariter moveri ex hoc ꝙ vapor adherens ei subtus vacat in circuitu. ¶ Et dicit dimetiatio motus circularis est a celo preter motꝰ naturales elementorũ et hoc ideo quia videmꝰ in elemento ignis similẽ motuꝫ circularem motui circulari celi in eo ꝙ apparet simulis motus circularis quandãm stellarũ incensaꝝ in igne que vident quibusdaꝫ horis in aere in loco supiori in crepusculo vespertino ita ꝙ videns credat ꝙ sint stelle quia videt moras motu simili stellaꝝ ꝛ sequentes ipsas vsq; ad occasum. ¶ Illius intentionis fuit etiaꝫ Hali et Albatahaꝫ cõmentatores Ptholomei in centiloquio suo qui dicit ꝙ sed stelle essentia ꝓsistat in vapore ignito sicut fit de asub et aliis flãmis in alto apparentibus. ¶ Ad hanc viam facit dictũ Albumasaris in libro suo de conjunctionibꝰ magnus libro octauo differentia prima vbi dicit ꝙ vna pars significatõnis in istis inferioribus est ex his methoroloycis impressionibus que in alto apparent sicut sunt ignes a sub et habentes comas et omnia

hec er vna materia ponit generari et ſubdit domin⁹ q⁹ hec elevatio maxime ſit virtute martis. Ex his igit̃ omnibus ꝯcludit q⁹ cometa ſit de natura elementari et nō celesti et hoc ſcōm oppinionē et ſententiā magis famoſorum philoſophorum ſicut patet.

¶ Capitulū q̃rtū de diuerſitate cometaꝝ

Ex quo modo dictū eſt q⁹ comera ſit exalatō calida et ſicca in ꝯcauo ignis acceſa tūc ſcōm diuerſitatē illius materie in mō ſibe eius poſſim⁹ q̃nq; ſpēs cometaꝝ nōbiliter differētes ꝯcludere et non plures ymaginando exalationē ex qua ſit comera hr̃e latitudinē et duos extremos termios quoꝝ vn⁹ ſit exalatio magis groſſa denſa et ſpiſſa Alter termin⁹ ſit exalatō magis tenui ſubtil et rara et quia int̃ q̃libz duo extrema eſt dare mediū qua ꝓpter eſt dare vnā exalationē ſimpliciter mediā inter extremū groſſi⁹ et extremus ſubtili⁹ vbi gr̃a ſic a groſſi⁹ z b extremū t̃miſſi⁹ z ſic c me diū int̃ a z b ſed tūc ꝯſtat q⁹ adhuc inuenit vna exalatō media int̃ a et c ſe tenēs magis ad extremū groſſi⁹. Et inuenit vna exalatō inter c et b ſe tenēs vſus extremū ſubtili⁹ z ſic habem⁹ ad hec duas dr̃as quib⁹ tles exalationes inter ſe differūt Et iſta igit̃ q̃ eſt inter a et c vocet d Et illa que eſt inter. c. et. b. vocet. e. tunc habemus ſic in toto ꝯnq; differentias notabiles illarum exalationum ex quibus poſſibile eſt cometas generari modo ſue ſubſtantie differentes et per ꝯſequens cauſantes nōbiles q̃nq; cometaꝝ ſpecies que per hoc differūt in magnitudine inter ſe ita q⁹ vna tūs ſpēs erit ſemp maior et̃ ſue aut clarior aut lucidior aut nigra aut lunda aut coloris rubei aut cerulei Aut coloris argēti et ſic de ſingulis nam lux in ſubſtantia alba clara et rara facit colorem multum album et lucidum. Et per oppoſitionem facit ſi ſit in ſubſtantia nigra denſa nam fulgidū viſum

in nigro vel per nigrum apparet vel efficat colorem ruſ
ſeum ſaltem ſecm apparentiam in illa eſt cauſa quare
non apparent omnes eiuſdem magnitudinis eiuſdē fi
gure eiuſdem coloris eiuſdē caude et de aliis z etiā qre
apparent in diuerſis locis et quare vna magnitudinat q
alia ceteris pribus in multitudine materie et hec eſt co
metaꝝ diſtinctio phica et naturalis. Aſtrologi tn po
nunt nouem ſpēs ſicut dicit Guido bonatus de forlivio
vbi ſupra auctoritate Ptholomei. ¶ Prima ſpecies vo
catur ceus et iſta eſt horribilis et non multum diſtat a ſo
le. ¶ Secūda ſpēs vocat tenaculus et eſt de natura mar
tis et eius coloris ferrei et habet comaꝝ in modū fumi
coloris cineris. ¶ Tercia ſpecies vocat apud illos par
uica et talis habet radium groſſum. ¶ Quarta ſpecies
vocat inuies et eſt de natura veneris et certā ād quitta
tem lucis cum radio longo ¶ Quinta vocat dñs aſtro
rum et eſt cometa paruus reſpectu aliorum et habet longā
caudam quam aliquando extendit in altum ad modū
ale. ¶ Sexta vocat matuca et eſt de natura martis et
vocat etiam autoria et eſt rubea et habz cauda ſatis lō
gam. ¶ Septima vocat argentum et eſt coloris argen
ti puriſſimi et fundit clariſſimos radios de ſepmo dicit
q omnium ſtellaꝝ nocturnaliū excedit clariſtatē et eſt
nature iouis Et ſignat frequenter bonam diſpoſitio
nē aeris et hoim. ¶ Et eſt octaua ſpecies que vocat ro
ſa et eſt ſatis magna et rotūda et ꝓſpicit in ea facies ho
minis Et eius color eſt ſicut auricalcū. ¶ Et eſt nona ſpe
cies que dr nigra et eſt de natura ſaturni obſcuri coloris
z liuidi et nullū boni ē nūcia ſic nos aliq̄ ꝓdictaꝝ pt argē

¶ Capitulū quintū de ſigtiōe cometaꝝ. (tū

Eſſet amplius in gñli videri ād ſigcent comete
qn appāt et videt. ¶ Pro quo nōdū q ꝓmeto
ri ſcōz ātiqs obſuacdes ē ſp nūcius d'oz effect

furuꝛi valde notabilis vl aliqñ plures diuerſi eueneñt eueniꝛ. ¶ Vnde ſpialiter Ptholomeus nõnt plures eſſectꝰ quos ipſe et ſui anteceſſores vt plurimũ obſeruauerũt et p aliquibꝰ illoꝝ ꝓcordat Ariſtotiles prio methoroꝝ. Similiter Iſidorus libro tertio ethimologiaꝝ capitulo vltimo de noibꝰ ſtellaꝝ et auctor de ꝓprietatibꝰ rerũ idem dicit auctoritate bede. Idẽ ſcribit Albertus magnꝰ et breuiter omẽs antiq et moderni pht in illis effectibꝰ omibꝰ aut aliqbus vt plurimũ ꝓcordauerũt quoꝝ primꝰ eſt motꝰ regũ principũ et magnatoꝝ tam ſeculariũ q̃ ſpiritualiũ. ¶ Secꝰ aeris ſiccitas. ¶ Tertius aeris motus. ¶ Quartꝰ eſt inundatio aquaꝝ ¶ Quintꝰ aeris corruptio et putrefactio ꝓpter q̃ ſequit peſtilẽtia ¶ Sextus eſt belle et prelia. ¶ Septimus ſterilitas terre naſcentiũ. ¶ Octauꝰ venenoꝝ plurimoꝝ. ¶ Nonꝰ mutatiõ regnoꝝ et depopulatiõ terrarũ habitabiliũ. Iſtos effectus omnes poſſumꝰ facialiter mõ phico et naturali introducere ꝓſupponẽdo q ꝓpleriões naturales, accidentales et aduentice mutãt hoũm iudicia deſideria et volũtates. Illũ manifeſte patꝫ quia alioꝝ moꝝ eſt melancolicꝰ et ſanguineꝰ, flegmaticꝰ et colericus patꝫ eſt am illud in iſtis qui infirmi ſunt et in iſtis qui ebrieſi ſũt ꝓpter enim accidentalẽ diſperantiũ ſuaꝝ naturaꝝ coꝝ mutãt iudicia et volũtates. Iſta ꝓpoſito ſal patꝫ q iſte ſtelle comate ſignificãt ꝓtriões et bella pdictq eſt ignũ q exalatiões calide et ſiccemultũ dñant tunc qui dꝰ aer nos ãbigenes inficit et infectꝰ eſt. Sed de marime alterãtibꝰ naturã mram eſt aer. ¶ Vnde tunc corpora nra vltra ꝓſuetũ caleſiũt et deſiccant et mutant ad colericoꝝ naturã qui promtiſſim ſunt ad irascendũ et erũt animoſiores et magis furioſi et ad vindicandũ illaras iniurias magis pati et ſic ad bella ad prelia ad ſeditiões maxie puocant inf omẽs hoies bella portes

erigere. Tūc reges et principes sunt maxime potentes
Vnde tunc illis ad pliandū dispositis quia passionibus
resistere nolūt bella incipiūt quibus pactis altera pars
frequenter vincit. Altera subcūbit ⁊ isto modo occidūtur
reges principes et magnati ⁊ viri nobiles ⁊ sic habem⁹
causam belloꝝ et mortē principū ⁊ aeris siccitati decla
tā. ¶ Verū est qñ aer est sic dispositus et talib⁹ vapori
bus pnitet⁹ humana morbo ledunt corpa sed principal
quia delicatiores sūt alijs citius ledunt etiā qi in prīmē
ter viuūt vñ mortales morbi eis facilius et citius cete
ris ꝓingunt ꝓpter q̄ moriunt frequentius post appa
ritionē talū stellarum ꝯ alijs annis et dieb⁹. ¶ Quod
aūt significz mortalitatē et pestilentiā patz p̄ Alber
tum in libro suo methoroꝝ li. primo ca⁹ nono vbi dicit
qñ inflāmatiōes ales apparēt et ignes volātes et max
ime cometa tunc scias q̄ tunc multiplicant cause tem⁹
pestatū et ritatū et pestilentie ex aere venenoso qi scin
tillatiōes hmōdi sepe discurrētes p̄ aera cum aeris
materia sit vapor calidus et siccus cōbust⁹ corrūpunt
aerē et faciunt ipsum venenosum et maxime dispositum
ad generandū a. postemata et variolas et sic habem⁹
q̄rtum effectū. Quātē significēt multitudinē ventoꝝ pa
ret qi tal stella significat multitudinē exalatōnis cali
de et sicce modo non omēs exalationes tales ascendūt
sursuz in aēm ymo multe earum remanēt infer⁹ et nō
omēs ꝓuertunt in flāmas sed multe earuz faciunt fla⁹
tum ventorum et seruiunt p̄ ventō. Est enī materia vē
toꝝ exalatio calida et sicca vt patet .ij. methoroꝝ vn
de ex hoc ꝓcludit multitudo et fortitudo ventoꝝ ꝓpter
multitudinē cause materialis eaꝝ ⁊ sic patz q̄nē⁹ et quo
sequit⁹ iustus effect⁹ salicz terre mot⁹ nam qñ multipli⁹
cant⁹ tales exalationes tunc nō solum multiplicant⁹ in ae
re et sup̄ terrā verūz etiam magna habundātia eaꝝ in

cludit et claudit in tre viscerib⁹ et cauernis et ibi in illis locis multiendo exalationis existat et generet intantū q̄ manere nō possit neq; claudi aut q̄ ꝓter aliq̄s causas ibi rarefiat et velle hīre exitū et non possit aliter q̄ violentia q̄ strictissima loca et an fractus erumpit et etiā aliq̄s quintegras terre ptes ipsas tumpedo ad extra ve hementissime trāsit vñ tunc fit concussio magna que voca tur terre motus⁹ erquo fiūt duo mala. ¶ Primū est destru ctio edificior̄ vt scribit Seneca q̄ olim due insule sub⁹ merse fuerūt in mare ꝓter terre motū et anno dñi m°. ccc°. quinquagesimo sexto basilea corruit in magna pars te ei⁹ terre motu et anno dñi m°. ccc°. quadragesimo octa uo villarū in Karinthea terre motu corruit et magni mo tes et castra ceciderunt. ¶ Sedm malū q̄ surgit ex ter re motu est actis venenosis⁹ et terre nascentiū mala dispositio ꝓter q̄ sequit mors et pestis hoīm et pecco rum vt sepe visum est et tunc ꝓter talē vapor⁹ exeun tem de terra et exalationē calidā et siccam in aere am biente terre nascentiū radices efficiunt aut alio quodā modo male disponunt. Aut subtrahit eis deritū alimē tum. Vnde tunc terra erit sterilis et nihil generat de quo hoies viuere debeāt et sequit karistia habem⁹ igit̄ nunc p istas mōm causam terre mot⁹ et venen⁹ pluralitatē. et karistiam expeditā ¶ Sed q̄do fiant aquaꝝ inunda tiones illud sic patz q̄n ceni hūt fontes et mlte ebre resolu unbes fiūt etiā tūc mlte aq̄e in vapores inuersiōem et pl⁹ solito ꝓter q̄ fiūt mlte pluuie et specialit tpe ꝓpo tionali vñ tunc augent̄ stagna et flumina vltra ꝑsuetū et solitū in ipsa ex humiditatib⁹ inclusis in terre viscerib⁹ fiunt vapores multi in aquā conuertibiles quare flumi a augmētant̄ contingit etiam q̄ ꝓter terre motum aque clause apperiunt̄ per casum ꝛ remotionem obstaculi et aliq̄n fluentes aque in suis meatibus claudunt̄ vñ exitꝰ

nequeũt niſi augmentate nimiũ et tunc ſit violent⁹ eo⁹
tum eruus per ruptura et ſurgũt inundaciões et in op
pinat⁹ aquarum inſul⁹ qui ſubmerſionis unius punct
e vel ciuitatis terroũ incueit et ruinam ⁊ ex his ſurgit
q̃ terra inhabitabil erit habitabilis et ẽ ꝑuerſo que eſt
habitabil erit inhabitabil q̃ etiã depopulationis cau
ſa exiſtit ꝓter plia qñ et lites ꝓtinuatas fiũt etiaz re
gnoꝝ et puinciaꝝ depopulaciões et ſic patz breuis oim
ꝓdictoꝝ effectuũ introductõ ꝓbica ⁊ nalis ⁊ hec õ iſta

¶ Capitulũ ſextũ õ diſpoſitõe et ſorma ꝓme
te et ei⁹ ce lore quia apparuit his diebus

Anno pñti ſez ãno dñi m⁰ cc⁰ lxx⁰ ij⁰ 1402
a q̃ circa pncipiuz februarij apparuit primo
cometa apud nos in ſuenia multis et adhuc
vidim⁹ eum in vima die quindecima marcij et 20 ⁊. die
verſus occidentem ad partem ſeptendrionis declinan
tem et in eo videre in contactu orizontis occidebat vbi
ſol occidere ſolet dum ſolſticij punctum obtinet eſtua
lis Erat autem quantitas eius totius maior q̃ minor
ſicut eſt quantitas veneris qñ ante ſolis ortum ſup noſ
trum emergit emiſperium. Sed non tante claritatis ⁊
eius color ſicut color veneris qui q̃ſi ex metallis ſimilat
in eius luce et cauda ſua p aliquod ꝑuus fuit color⁹ al
bi non valde longa ſurſum erecta ſpiſſa q̃ſi ſicut ſcopa
ſpiſſa et hec cauda in principio declinauit aliquantul
ad meridianas partes poſtea magis per longitudinez
ſeptimi climatis deinde cauda nõbiliter õclinauit ad ſep
tẽtrionẽ et creuit in groſſitie ⁊ fulgore eneo manifeſtiſ
ſime ita q̃ circa q̃ndecimũ diẽ martij apparuit in lon
gitudine vni⁹ lãcee et media in forma piramidali figure
linialiter ꝓmẽſurate cui⁹ latera ꝓcurrebãt in ipo ꝓme
ta ⁊ baſis ꝓxime õi ſuperiori ꝓxi diffuſa p ſaz latã di
ſtãciaz ymo ego nõq̃ vidi ita lucid⁹ ⁊ coloratã caudã

sicut tunc. Et nota q circa principiū apparitōnis eius mars fuit in ultima fame arietis vel circa eaz sed tunc non vidi cometā sed postea per locaz lune inueni q cometa debuit similiter esse in terria facie seu ultima arietis. vnde nulli dubiū q mars venit ad p̄iūctionē comete. Ita q in isto tempore aliqñ fuit verū dicere q circa sol⁹ trāsiens p polos zodiaci et p mediū celi ibat etiā p citra vtrusq; imo vicesima sēda die marcij visus fuit hora sēda ꝑpe solem ad distantiā lancee versus septētrionē. Vnde tunc patz q a septēptrione p magnū spaciū mot⁹ est obuiādo soli transiens aliter versus orientem vidici et ibi similiter in festo pasce hoc est 26. vel 27. die tunc disparuit cometa. Sed in oriente ante ortū solis vestigiū eius apparuit quia tres longas comas vidi et multum grossas et post occasum vidi vnam comam in occidente et quia mars est nature calide et sicce et similiter aries est signū eiusdez nature quia de triplicitate ignea et cometa est ex exalatiōe calida sicca vñ est estimandū q opus eius erit multū ex operatōne et virtute ignis caliditatis et siccitatis et specialiter ꝑ oriētali

¶ Capitulū septimū de significatione comete p̄sentis anni naturaliter introducte. 1402

E significatione comete āni p̄tis in gñli possum⁹ dicere q significez eius effect⁹ futuros qui ista tm in capitulo quinto sunt annumerati. Vnde omēs comete causātes fuerint dispositiones habent ꝺn in ō ad hoc et similiū causis fieri et per ꝯsequēs similiter nunciare modo p̄dicto in cōm plus vel min⁹ q materia a q⁹ est maior vel minor spissior vel rarior et in vna parte plus q̄ in alia sēm q fuerit distātior vel ꝑpinquior vel sēm q materia sua fuerit calidior et fortior vt mel. vel debilior et etiā sēm q diuti⁹ durauit vel breuius

omēs circūstantie iste alleuiāt vl aggrauant effec⁹ et
significatiōes sibi attributas. ¶ Et ideō dicendus est de
isto comete q̄ etiā signat lia et huiⁿmodi mala prius
dicta que ꝓter sui apparitionē et existentiā sunt ferēn
da ne aliq̄ eoꝝ eueniant hominib⁹ et̄e subsequēti. Attēn
mē magⁱ particlariter possim⁹ naturali ꝓcessu inues
tigare circūstantias siue significatiōis quantū ad na
turā effect⁹ quē habent ꝓducere et quantū ad loca ter
re in q̄bus huiⁿmōi significatio debeat apparere et ꝓp
hoc ego ponā aliquas suppositiōes. ¶ Prima q̄ nisi ap
parat q̄ non ꝓter causas naturales q̄ nunc sit colecta et
que resoluāt ꝑdurando debeāt in nobis ales fieri altera
tiōes et in aliis rebus. sed credo q̄ p totū tem⁹ ꝓteri
tū in quo incepit illa materia colligi ꝑ ales inducte sint
ibi in magna pte dispositiōes ſuuātes et ꝓparantes ad
talē effectū ꝓductionē. ¶ Secūda ego credo q̄ tal ma
teria tpe longo colligi non cito. ¶ Tertia suppositō q̄
ab vna plaga terre plus tal materia resoluit q̄ ab alia.
Illud patz de se quia cometa magⁿ ꝑmanet apparens
versus septēptrionē q̄ in alijs ptibus celi licz in occidēte
et oriente et versus equenoctialē et zodiacū possit ap
parere ꝑ versus ptes septēptrionis magis apparet ex
tra zodiacū et hoc est quia ibi non manet calor ita ad
ustiu⁹ et ꝑsumptiu⁹ sicut in alijs ptibus celi. ¶ Quarta
suppono q̄ si esset notus de qua p terra essent plures ex
alationes fuissent elemata horū fieret in qua patria ta
les effect⁹ eorū⁹ eueniret patz illud ex dictis q̄ tunc in
illa patria maiores siue natiue alterationes fecissent ꝓp
ter eoꝝ ꝑsentiā vt clarius est. ¶ Quinta suppositio que
cūq̄ viuentia essent calidioris et siccioris nature talis
impressiō talū esset magis susceptiua patz istud simi
le additū simili facit ipsius magis tale. ¶ Ex quo patz q̄
hoīes colecti essent magis ad hos effectus dispositi q̄

flegmatici et sic de alijs etiã non viuẽtib⁹. ¶ Istic post
te nota tres in aere dispositiões quaꝝ ego sum memor
q̃ nõ est diu q̃ vna post aliã successit p ambitũ nr̃e res
pue in sueuia. ¶ Prima fuit ãno dñi. m°. ccc°. 99°. aut
in vigilia aut aut in die psessiõis scti pauli de nocte dũ
fierent tenebre satis post occasum solis et iam nemo si
ne lumine vidisset in domib⁹ venit vna vniuersalis lux
in aere et vniformis more sicut fiũt corruscatiões ꝑ diu
tius manst̃ ꝓa q̃ visibila in posteriorib⁹ pribus domorũ
appariuerũ Ista lux non fuit ab aliqua stella nec a lu
na nec a sole nec a reflexione alicui⁹ luminis vt manife
stũ est sed a flãma quadã cui⁹dã vniformis explatiõis p
totũ visibilẽ orizontẽ spere simul ignee et flãmã lucidã
faciẽte. Ista dispositio in aere fuit visa credo ãno do
mini q̃dringentesimo circa aurũpnum tunc venit p aerẽ
vna flãma longa ad lõgitudinẽ lancee habẽs caput q̃
si sicut vitulus et videbat ꝓtinue stricti⁹ vsq; visus cau
dã et venit ab occidẽte versus orientẽ sat' more se mĩsi
ens p aerẽ et in pinaculo vni⁹ dom⁹ euanuit me videre
nec habuit altitudinẽ vni⁹ turris et tales similes ignes ĩ
crepusculo vesperino in diuersis locis cadẽ hora p totaꝫ
sueuiã appuit ¶ Tertia dispositio ãno pdo scz q̃dringẽtesi
mo prio circa appũlẽ stati in pricipio veneris tonitrua
a ꝫ corruscationes duranerũt p oẽs mẽses vsq; ad finẽ
augusti q̃ non ẽ aliqs qui fuerit memor ꝛ tot et tales
pestarib⁹ tre nascẽtia frumẽta fruct⁹ ꝫ vineas destruẽ
tib⁹ imo ẽtiã q̃dã die ẽndinea tẽpestas hic vl'in pximus
dãpna non modica intulit cãpo et agr̃i Iste eni dispo
sitiões pñtez cometã figurabãt et mltiplicatas exala
tiões elevari ꝛ tra ꝓtinue certissime demõstrabãt ¶ Ex
quo sequit̃ q̃ cause comete materiales a pumia nra ꝫ
pribus pximis se multũ levauerũt ad aera. ¶ Ex quo vl
teri⁹ patz q̃ talis materia siue actionis vestigiũ in ista

patria et in omni alio loco vbi dispositiones illarum ppatu
erũt terris et lo.l ꝛ sitꝰ incolis dereliqt patꝛ ꝛ oriũ ex ſiu
positionibꝰ priꝰ tactis. ¶ Et quia hoies in septimo cli-
mate degentes a principio uꝰ vſq; versus orientez sunt
hoies vindicatum nutritũ et naturaliter alti corpore et
fumoſi faciliter irascibiles ad bella pati gaudẽtes de
rixis i vna tñ puincia plꝰ q̃ i alia et in vna ciuitate plꝰ
q̃ in alia oñ sicut ex francones similit bohemi vngari ꝛ
turci sunt gẽtes in bellici instrumẽti et armis gaudentes
et his exercitijs lõpacdia et ytalia mulcl tpibꝰ labora-
runt franagene similit in armis gaudent p lõginq̃ ans
regiones plus ceteris militarib̃ opm p̃cnia desiderant,
obtinere oẽs tales puincie et ciuitates illiꝰ nature sunt
et hanc impssionũ et sigacionũ comete suscepte magi
q̃ alie gentes et puincie que pacem magis q̃ guerras
suis tpibꝰ dilexerũt verũ est q̃ tales homies magis pa
cifici possunt puocari ꝓpter causas dictas et tunc hũt
aliqñ seniores alios. ¶ Ex quo patꝛ q̃ sicciora loca in p̃
dictis puincijs et reçionibꝰ sunt magis ad sterilitatem
terre disposita ꝓpter multas causas desiccatas humidi
tatl terre penꝰ destructres et hoies calide et sicce cõ-
plexionis sunt magis ad morbos et ritas pati ꝓpter si
milẽ causam et in omni loco vbi cũ tribus ꝙalitatibꝰ
est maior similitudo ibi euẽtꝰ furuꝝ sunt magis suspecti
et ciuitates sũt nec ẽca mõtanas aut fabulosas terre p
nos ꝛ ꝺesuetnosas tremotꝰ ꝓpter cãs p̃dictas posterũ
p̃cctis expectare ꝛ ira ferre possẽ has cãs ad reges
ꝛ p̃ncipes magis aiosos q̃ mobiliores fierẽt ad inuicem q̃
videtas et illi q̃ nõ sũt tãm pati erũt calidiores ꝛ p cõs
audatiores ꝛ incipiẽt res magnas aggredi q̃ priꝰ velut
placidi dimississent ꝑ vbi tales sunt nescio ꝑ forte inuenũt
seipos suo loco ꝛ tpe optũs ¶ Capitulũ octauũ de si
gnificatiõibus cometarũ secũm viam astrologorum.

Anno dñi 1460 [illegible]
[illegible]

Ed astrologi aliter dicūt ꝛ sig̃cationes eius aliter recipiūt ꝙ immediate añ sit exꝑssus. ¶ Pro quo est nōndū ꝙ astrologi ꝯsiderāt caudā et dicūt ꝙ versus quā ptem exercuit se cauda ꝙ ⁹sus illā plagā sig̃cationes supra dicte sint ꝯsiderāde Si sic ita tūc clarū ē ꝙ in pricipio inclinauit caudā ad latꝰ meridiei igit tūc ab occidente a pribꝰ hyspanie et francie incipiēdo et per montanas et lumpardiam et tales patrias significationes predicte forent applicāde sed per modū magis directe direxit se versus longitudines septimi climatis deinde declinauit ad septemptriones versus angliā Scotiam et versus partes inferiores almanie que sunt extra septimum clima vnde tales prouncie et talia regna haberent super his sibi effectibus pueri ꝛ ista est prima ꝯsideratio astrologoꝝ in quibꝰ locis debeant talia apparere. ¶ Est et aliorū astrologorum ꝯsideratio et isti ꝯsiderant de qua specie sit cometa de illis nouem ꝛ tunc sc̃m hoc prosticaciones eorū ꝯstituunt. ¶ Quapter nota ꝙ non inuenio de istis nouem speciebus aliquā cui possit tantum assimulari nisi tentaculo aut prics de tentaculo dicit Guido bonatꝰ de forliuio tractatus de relationū circa finē quā apparuit hic cometa qui dī tentaculū significat penuriā non tm̄ precedentē neq̄ famem simpliciter et sig̃t guerras de quibꝰ intermittent se ꝓsone ecclesiastice vltra q̄ oportz Et si sit prica tunc dicis ibidē ꝙ significz siccitatē atq̄ aquaꝝ pauciratē et pauciratē frumēcoꝝ. ¶ Et si fuerit ꝯplicata marti sig̃t guerras q̄ plurimas et mortalitates ꝑ gladiū et effusionē sanguis et ⁹bustiōes ignis modo sic est ꝙ fuit ꝯplicata marti igit dicūt ꝙ iste apparitiōes eius fūt in equi distātia arietis sicut ego credo nihil potui aliter ꝯprehēdere. Tunc dicit Guido vbi supra ꝙ tunc sig̃t magnuz malū atq̄ districtionē diuitū et magnatū atq̄ nobiliū

in ptibus ouerno et babilonie et multitudinē triſticie re
gū eū iuſticis ſuis et populariꝫ. ¶ Et alq dicūt q ſi fu
erit in ariete cometa tales ſigt tribulationes et triſtici
as ytalicis et romanis et ſi tuna apparuerit in occide
te magnates et nobiles male habebūt a regibus ſuis et
erit cedes hominū in occidente et ſigt nives et aquarū
inundatiōes et dampnū in multis animaliꝫ et precip
pue piis et ſi apparuiſſet in thauro q tamē non fecit
adhuc ſcōm aſtrologos ſigcaret illa que dicta ſunt et
adhuc pcoia. ¶ Scōm iſtos igit cuſtodiant ſe puintie
reges et regnū et ciuitates ſubiecte ariete t martī qua
les ſunt oēs hre et puincie ſupꝫ nominate quia omnes
illas ſcōm illos reputo eſſe multū martis nature. ¶ On
de āno dñi m°. ccc°. lx. vt dixi apparuit cometa et po
ſtea anno m°. ccc°. lxv. fuerit in breui tpe ab appitu in
aptendo tres magne ꝯiunctiōes triū ſupioꝝ ſcilz ſatur
ni iouis ſiꝫ vndecimū die appilis. xo. gdu gēminorum
¶ Et ꝯiunctio martis et ſaturni in q̄rto gdu cancri que
niſi fre de. xo. annis in. xo. ex omnes mala pnūciant de
eadē ꝯiunctiōe et fiebat ſep. vi. die iunij Jrez tertio
ꝯiunctio iouis et martis in ſigno cancri. xz. gdu et. xx.
die mēſis iunij vnde tunc eodē āno plura mala appare
rūt ſimul q̄ in aliquo aliorū annoꝝ. Vnde tunc timeo
q ſimiliter anno q̄nto hoc eſt p tres annos poſt illū eo
metā ſcilz āno. 1409. effectus ſi fieri debēās apparebant
magis gues q tunc q̄ſi antea in ianuario die duodeci
ma circa meridiē āno dñi. m°. 1409. erit ꝯiunctio ſaturn
ni et iouis que ſcōz Albumaſarē ſigt ſemp nominatos et
euentꝰ nobiles timēdū eſt q ſi longo tpe non fuerint an
dicti noui euentꝰ et graues et periculoſi ſaltē tunc appare
bant ꝓpter ſignificationē cometē t ꝯiūctiōes iſtoꝝ ma
ioꝝ ſcz ſatūi et iouis t hec ſufficiāt de ſigcatiōibꝰ huius
mōi cā ſcōm vlā naturalē q̄ ſcōm poſitionē aſtrologoꝝ.

¶ 3

¶ Capitulū nonū in quo ꝓnūt exēpla cronicā antiquoꝝ ⁊ modernoꝝ ſup ſignificatione cometarum.

Lantriꝰ hiſtorijs legit i multiloc quō anteq obſuauerūt nōbiles euēt⁹ q̄ ꝯſp ꝓ⁹ apparuerūt ꝯmete apparuerūt ⁊ ꝓp hoc ſub breuitate volo aliq̄ hyſtorias eius tā nouas q̄dā et veteres ꝓbāre. ¶ Itē legit q̄ tpe nat̄onis fuerūt tres ꝯmete ſucceſſiue et tūc viuerūt ſc̄⁹ Petr⁹ et ſc̄⁹ Paulus iuſſu dei p̄dicā tes et doctores fidē catholicā ¶ Itē legit q̄ tpe veſpaſiani impatoris ꝯmeta apparuit ⁊ p pauꝝ p⁹ capitalīū rome igne ꝓbuit ⁊ tūc ſtati p⁹ eye⁹ vadit ꝓlim et ſubuertit illā a fundamēto cū iudeoꝝ ſtrage vēditiōe et p vniuerſum orbē diſperſiōe. ¶ Itē tpe Cōſtātini impatoris ſtella ꝯmeta apparuit ⁊ ſtatī moriēte ¶ Item tempore iuſtiani impatoris apparuit ꝯmeta et morbo mortif iuſtian⁹ ¶ Et 1060 hyſtorijs āglicanis legit q̄ āno dñi. m°. 60. normanni et pūgnauerūt totā angliā ⁊ ſubiugauerūt eā ſibi. ¶ Itē 1160 tpe heinrici ipatoris apparuit ꝯmeta ſcz āno dñi. m°. c. 60 ⁊ deuic⁹ fuit in p̄lio impatoris alem⁹ ꝯmatis cōſtātino politan⁹ ¶ Itē tpe friderici ſcōdi ipatoris āno dñi m°. ccz 1222 apparuit ꝯmeta et guerre plurime in lōbardia apparuerūt ¶ Et bonor⁹ papa mortf et gregor⁹ creat⁹ et orta fuit diſcordia int̄ gregoriū ⁊ friderici ſcōdi ipatoris de q̄ multa mala ſecuta fuerūt et fūt vſq̄ mḡ kariſtia et tūc rex caſtelle expulit ſarracenos de hiſpania. ¶ Et rex arragonie cū armata mānu ⁊ hoſtilit inſulas maioricā⁹ obtinuit ceſpas maioricā ſibi expḡnauit ¶ Eodē āno frideric⁹ impator ꝓmo genitū ſuū heinricū incarceravit 1229 idē in carcē mortu⁹ eſt. ¶ Itē āno dñi. m°. cc°. 29. apparuit ꝯmeta et p⁹ ſeptim eſt bellū int̄ piſanos ⁊ ianuas ⁊ capti fuerūt multi baſani. Itē Ouidius Nasa⁹ in li. ſuo de remoluciōib⁹ āno q̄ circa finē in capitulo de ꝯmeti recitat

suo tpe vidisse cometā ꝛ statī p⁹ apparitionē ei⁹ qñ fuit Ēra arabum .602. circa annos dñi. m°.cc°.60 quia tūc 126
viverunt beatus Thomas de aquino et Albert⁹ magn⁹
mortu⁹ fuit papa Alexander et non multuꝫ p⁹ fuit mor
tu⁹ Mānfredus rex cecilie per quēdā fratrē regis francie
q̄ vocabat Scharlott⁹ et iste fuit comes pruncie et nō
multuꝫ post fuit interfect⁹ rex Conradus rex apulie
multi nobiles secū Et non multū post fuit infect⁹ q̄d az
frater regis castelle nomine Frideric⁹ et multi nobiles
viri secuꝫ et multa mala venerūt p⁹ illum cometaꝫ qui
satis diu duraverūt. ¶ Jtē q̄daꝫ in quodā suo tractatu
de assiꝫ pestilencie recitat se vidisse cometaꝫ anno dñi
m°.cc°.37. circa festū sancti johānis baptiste Et rūc in
cepit bellū inē victissimū regē francie Philippū et glo
riosissimā regē angliā Edwardus q̄ prelū plangendū
fuerat erat aūt nouale inter p̄dictos reges āno dñi. m°
cc° 40 in natiuitate johānis baptiste Et fuerūt de pte
veriusq; regī ꝛ interfecti in mari suffocati ꝛ capti circi
triginta milia hoim. ¶ Jtē anno dñi.m°.ccc°.42. eraꝫ
parisi⁹ et tūc circa festū nativitatis bte marie virginis
appuis cometa paru⁹ et humilis q̄si in isto loco vbi ap
paruit cometa huius anni et nō multū p⁹ vix per duos
mēses rex francie cuꝫ magno exercitu vt dicebat cū plu
ribus q̄ cuꝫ centū milib⁹ equis venit in adiutoriū comi
ti flādrie contra gandauenſ in flādria et venerūt ad
p̄liandū et bellandum Et dicebat p vero q̄ de viraq; p
te et maxime de civibus gandauēsiū occisi fuerūt vltra
triginta milia hoim rex francie rediit in regnū suū cum
duce britanie q̄ ista vice fuit regē francie Et cum toto
exercitu suo hostiliter parisienſeꝫ civitatē intrauit Et ibi p
ter seditionē q̄ndaꝫ anno. 21. inceptā per parienſ cives
sedavit per maximā parisiensiū civiū persecutionē. ¶ Et
porta sancti Anthonij fecit rex fieri pulchrum castruꝫ

patisses cathenas p totã ciuitatẽ amouit omnia ar-
ma ab eis abstulit et sic omnes rebelles non solum pa-
tri⁹ verum etiam in aliis ciuitatibus circa vicinis ad
obedientiam per quissimas penas reduxit ¶ Dux ande
nagens patruus regis francie nunc viuentes cui in au
ditus dimictis et maxima gente pro optinendo regnum
appulie contra regem Karolum in appuliã venit et bo
no tempore in regno illo mansit finaliter venit postea
inter gentem suos Et euanuerunt omnes Et mortu⁹ est
comes Subaudie et ipse dux anno domini. m°. ccc°. lxx.
de mense septembris mortuus est et multi nobiles viri
ibidem peste fame et tristicia perierunt et factum est ꝺ
exercito isto ac si numquam fuisset excogitatus

¶ Item anno domini mcc. lxx. circa festum sancti jacobi
venit vnus episcopus contra regem francie de anglia
cum sex milibus lanceis ad destruendum terram regis
francie contra quem rex francie iterum maximum ex-
ercitum congregauit. Sed sine prelio cum treugis an-
glicorum gens in bona pace ad propria remeauit.

¶ Item statim post scilicet anno. lxx. circa medium ja-
nuarij dominus papa Vrbanus sextus quinq cardina
les vinculis grauissimis inclusit postea demuciis p̃ma-
nere graues recessit et remãsit sine capite romane cu
ria⁹ bene decez septimanis q̃ nesciebat vbi in mũdo pa
pa foret et suos capens secum duxerat cardinales sua
liter per conductum januens̃ permanere remeando ad
ianuam diuertebat et ibi per tempus notabile moram
traxit Item eodem. lxx. de regno vngarie expellitur rex
Sigismundus tra q̃ vix vngarionum manus euasit Et
in continenti vngari de consensu ambarum reginarum
matrũ videlicet Et filie marie vxoris regis Sigismun-
di arma expulsi mittũt legationẽ solẽpnẽ ad regem Ka
rolum de pace regem appulum ipsum q̃ in vngariam

ducte et regni vngarij coronā cū magna regali solemp
nitate put regibus ꝓnuit contulerūt. Et post duos mē
ses vir pdict⁹ Karolus rex vngarie p suos emulos et in
sidiatores fuerat impie per scua sui capiti vulnera cru
cidat⁹ postmodū rex Sigismundus in regē vngarie as
sumt magnus comes vngarie amoto capite mortt re
gine ambo capiunt et multa in vngaria fuerant in bre
vi tpo per hunc cometā ptracta. ¶ Itē eodē anno. &
magne fame et potentie vir dñs Barnabas capit⁹ in
carceribus mortt. dñs Marchio ferrariensis a popula
ribus⁹ ex pelluk et vrbe Bononiensis p⁹ modū in dnm resti
tuit. ¶ Itt. & 6. inter ferrariēsis dñm et paduanū guer
ra ortt ferrariensis dñs similiter victus a suis de verona
fugat dñs Galeaz mediolanensis in domine succedit
impie verona depredat. postmodū statim dñs Padua
n⁹ per eodē dominū mediolanensem capitur et idem in
carcerib⁹ mortuus est. ¶ Anno eodē anno. & 6. hoc est
anno quarto post appariticnē cometa in confinib⁹ mō
tium suevie in bello dux Leupoldus dux austrie etiā mo
ritur et multi viri nobiles et strenuissimi suā cum eo vi
tā virili animo pdiderunt. Et anno. & 2. antiqua lis et
guerra inter terre dños et imperiales suevie ciuitates ite
rum innovat ex quo multa mala secuta fuerunt in sue
via ex quibus concludit exemplariter q predicti euent⁹
superius notati non solum in primo anno expectantur
verū etiā plures anno post ei⁹ apparitionē male sue sui
gnificatiōs potenūt euenire. ¶ Fluctuās enī mare etiaz
cessantib⁹ ventis et tēpestate sedata non ꝓterea hescit
¶ postmodū adhuc tpestat⁹ piculū immineat ac si vens
tor flat⁹ in virtute sua maxima pmaneret. In medicīa
enī legitur q: morbis amotis de humano corpore non
ꝓterea sp morbor tollunt accidētia q ꝓterea possibile
q ān⁹ pīus fiat satis fructuosus ymo possibile est q res

ñ predant ex his sic fierent eñ de ꝓdictis significatio-
nib⁹ et effectibus libertꝫ p annis sequentibus non esse-
m⁹. ¶ Unde patꝫ q a tpe apparitionis huiusmõi ꝛne
ejusce sus p sex annos ĩclusiue q est sacie breue et re-
pus inopinabiles euent⁹ magnatuꝫ terrã inter homes ho
salutez figurãt omniũ illoꝝ post ipsuꝫ comerã. Ego sum
memor et si in psso deficio annoꝫ tpe aliqua ex factuꝫ e
rea ee non multuꝫ distant predicti euentus a tpib⁹ pre-
notatis.

¶ Capitulũ vltimũ in quo ostẽdit q
fideles catholici non debent aduerte
re nec illã nec aliaꝫ stellaꝫ figuꝛas

Ed quicqd in precedentib⁹ capitulis dictũ sit
ymaginabile est et simuliter credendũ q nos-
stra venerãda pcha Et vane preceptoꝛuꝫ dei
trãsgressiões et sine dubio irefrenata cupiditas seu cõ
cupiscentia que non poterit debitis limitibus et ꝓpꝛie.
Inque ausu sibi vendicat aliena que nostris nunc tem
poꝛib⁹ heu valde multiplicant et intrepide a non nullis
etiam q stat⁹ eam secularibꝫ spiritualiũ ꝓsonaꝫ gerr
lesie ita videliz q ch̃isti militans sponsa non videretur
a capite vsq ad plantã pedis tanta pcoꝝ vulnera p
omnia sua mẽbra vnq habuisse q̃neo his tpib⁹ iustus
sue fallor. Et si mãnuꝫ tribulationũ cause non surgerẽt
ex nob aut p nacctra pcm simile est q mãa sacmoꝛa his
intris adhuc iubente et ꝓmittẽte deo etã de nouo creã
re penas nlq ꝓmanerẽt ĩ vita. Ib enĩ a fame nec pmet
pos torquent sed pcha que facim⁹ numeꝛo carencia tri
stissimas meꝛoꝛes mortes morbos famẽ guerras et alia im
pedimẽta q plurima sup nos euocãt et dolores. Querãs
igit nostra capita medicũ et immẽse egritudinis medi
cã assumant vt sanent tãe paul dubio ꝓficiẽtes saluti fi
goꝛ in celicis mẽbris resurgentes et cuncta vulnera sanãt

sponse militãtis ecclesie terre ꝓmittas sponse cũ ipso
to eterne salut' actoꝛẽ qui p' modũ sue ꝓprie militantis
ecclesie pãcẽ retinuerãq; a malis custodiam bonis ꝓfec
tum gubernet atq; omne hui' mũdi tpaꝛ elementa regulet
Lyon q' influant sed q' ꝓficiant non q' dominẽt sed q'
seruiant astra sua vult q' prosint melius eoꝝ influẽtia
et actiõe ꝓmouẽdo p eterna salute et beatitudine lar
gitur omnia prebet ita q' possit omnia remote deuto ig
nibus et aere volantib' cometis ut igne ꝓfulgentib' ꝛ in
ecto precipere astris et illoꝝ naturas si quas haberem
generi humano ꝓtractas Auxilio dñi nri ihesu xpi ma
dicamus reperiem facilius ꝓmutare qua q' ter dum
nostrũ thesus xpm ꝓcordialiter contemplemur et pis affe
ctib' ipsum rogem' et hortemur p intercessione gloriose
sssime q' virgis marie ut ipse dignet humanũ gen' a pe
culis omnib' custodire a malis defendere et dare gratiã
ꝑcta resistere et specialiter militantis ecclesie sue spon
se i trãquilitate mẽti ꝛ pace sumitatẽ dirigere salutarẽ

¶ Cõpilat' est iste tractat' et ꝓlet' per Jacobum an
gelu de vinea mgrm in artib' ac licentiatu ũ in medicina
phũ illustri principis. principis ducis Leupoldi ducis auste.

Appendix B.

TOSCANELLI'S MATHEMATICAL COMPUTATIONS*

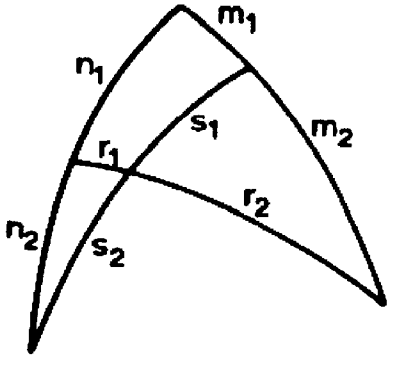
Fol. 245 r of Toscanelli's manuscript B.R. 30 (see plate VI, p. 75) appeared to Celoria to be a page of random calculations, and he addressed himself only to the words (Celoria 1921: 6). However, attention to the calculations themselves reveals some interesting information on Toscanelli's mathematical and astronomical sophistication. For convenience in discussion of this page, I have marked sections and numbered them.

Section 1 says at the top, "If you want to multiply a number by itself or by another, this is the way". There follows a sample multiplication problem of 15; 20, 24, 32 times 25; 23, 15, 12, both written sexagesimally, and the answer 6, 29; 26, 55, 54, 28, 54, 24, which is correct: he has then converted the 6, 29 to 5, 89, probably to make it easier to subtract some other number from it. The numbers are identified as degrees, minutes, seconds, and thirds. I have not been able to determine whether these numbers have any particular significance; they are not any standard astronomical parameters or chords of any obvious angles that I know of. The numbers do not appear elsewhere on the page. Interspersed with the numbers of the multiplication problem are other numbers, apparently jotted down in available spaces, which do not seem to be related to the problem. One of them, 113; 37, 54, appears frequently below.

Section 2 begins, "If you want to divide, in this way the first by the second", then "quotient number". There follows a long division of 54; 41, 13, 30 by 4; 53, 25, 10, the answer being 11; 10, 57, 45, 45, again with the numbers identified as degrees, minutes, seconds, thirds, and fourths. There are some errors which are crossed out, and the note "subtract from this" appears several times. There are a few extra numbers jotted in here also. The quotient is repeated.

Section 3 is a small diagram which appears to be an eccentric model. The outer circle was drawn with a compass, the inner one free-hand and tangent to the outer. The numbers inside are 60, perhaps the radius of the large circle, 10, perhaps the short side of the small triangle, 48, perhaps the radius of the small circle, and something which might be a 17, a 14, or an erasure. It was apparently drawn before the computation which was written above it, because that computation, which I will return to, is crowded around the diagram.

Section 4 contains two sets of six numbers, each equated with two letters enclosed in a semicircle thus: (ea). Each of the two sets fits into a Menelaos configuration. This relation, due to Menelaos (1st century, A.D.), is preserved in Ptolemy's *Almagest* and in Menelaos' *Spherics*, which we have in an Arabic version. (My discussion is taken from Neugebauer 1975: 26–34.) It establishes the relationships among six of the eight great-circle arcs in the configuration shown:



The outer parts: $m_1 + m_2 = m$

$n_1 + n_2 = n$

The inner parts: $r_1 + r_2 = r$

$s_1 + s_2 = s$

* A portion of this appendix has been published elsewhere (Jervis 1979).

The Menelaos theorem can be expressed two ways. Theorem I gives the outer elements expressed in terms of the inner elements:

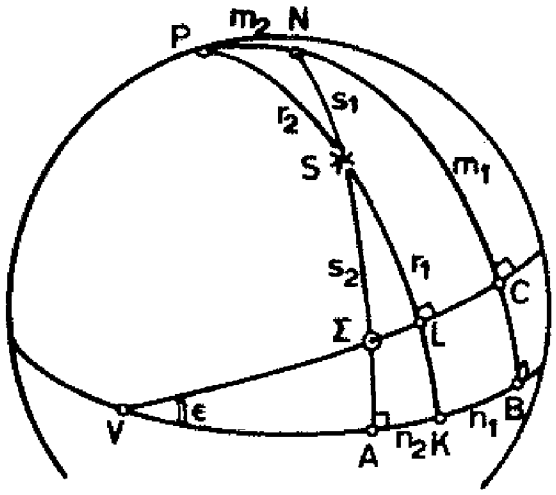
$$\text{(I)}\quad \frac{(m)}{(m_1)} = \frac{(r)}{(r_1)}\cdot\frac{(s_2)}{(s)} \quad \text{or} \quad \frac{(n)}{(n_1)} = \frac{(r_2)}{(r)}\cdot\frac{(s)}{(s_1)}$$

where $(a) = crd(2a) = 120 \sin a$.

Theorem II gives the inner elements expressed in terms of the outer:

$$\text{(II)}\quad \frac{(r_2)}{(r_1)} = \frac{(m_2)}{(m_1)}\cdot\frac{(n)}{(n_2)} \quad \text{or} \quad \frac{(s_2)}{(s_1)} = \frac{(m)}{(m_2)}\cdot\frac{(n_2)}{(n_1)}$$

Neugebauer shows 1) the derivation of these relations from plane geometry and the basic trigonometry of right spherical triangles, 2) that theorem I can be derived from theorem II, and 3) that any problem which can be solved by the trigonometric formulas of right spherical triangles can also be solved by the Menelaos theorems (Neugebauer 1975: 26–30). The Menelaos theorems were from antiquity the basic tool for solving problems in spherical trigonometry. They imply the standard spherical trigonometric formulas. Suppose, for example, that we know the location of a star (or a comet) in ecliptic coordinates, λ and β, and we wish to find the equatorial coordinates, α and δ. In the figure (Neugebauer fig. 26: 1215): if we know λ



= VL, and β = LS of the star S, we can find α = VA and δ = AS as follows: From tables in the *Almagest*, if we know VL we can find VK (*Almagest* II, 8: table of sphaera recta) and if we know VK, we can find KL (*Almagest* I, 15: table of declinations). So in the Menelaos configuration BPSA, with the vertex at B, we know the following:

m_1 = BN = 90°

m_2 = NP = ε, the obliquity of the ecliptic

r_1 = KS = KL + LS

where KL and LS = β are known

r = PK = KL + PL

where KL is known and PL is 90°

s = NA = 90°

Using theorem I, we can find s_2 = AS = δ. Then, because we know

s_2 = AS = δ

s_1 = SN = 90° − δ

n_1 = BK = VB − VK = 90° − VK

$m = \mathrm{BP} = 90° + \varepsilon$

$m_2 = \mathrm{NP} = \varepsilon$

using theorem II we can find $n_2 = \mathrm{AK}$. Then,

$n = n_1 + n_2 = \mathrm{AB}$

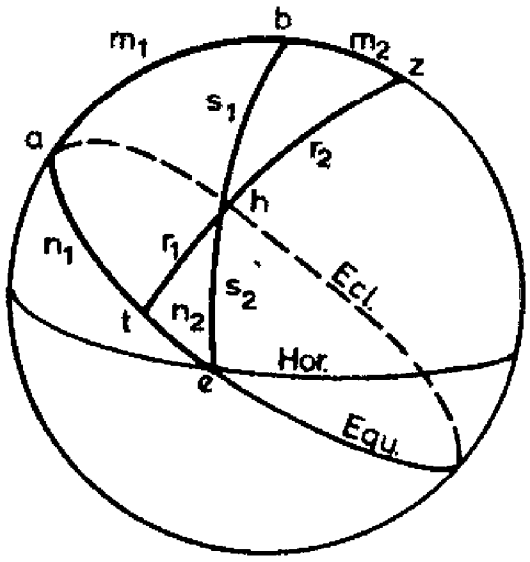
and

$\alpha = \mathrm{VA} = 90° - n$

Transformation from horizontal coordinates to equatorial coordinates requires, of course, that the latitude of the observer be taken into account.

There are several sets of numbers on Toscanelli's fol. 245 r that can be arranged in configurations like these. They seem not to be problems, because all six quantities are given; there is no unknown. However, in most cases four of the six quantities are nice round numbers or, for example, include the obliquity of the ecliptic and its complement, so we can assume that the unusual numbers are the quantities sought.

I should like to return now to the numbers in section 4. They can be assembled into the Menelaos configuration shown, in which the letters *a, t, e, b, h, z* are Toscanelli's, and the *m, n, s, r,* are Neugebauer's and, in Toscanelli's notation, $\overline{ea} = \mathrm{crd}(2ea)$.



This is not a unique arrangement for this set of numbers, but it is the only one I have been able to find which both satisfies the Menelaos relation and makes sense as an astronomical problem, namely, at what latitude and at what time will the sun at summer solstice be due east at an altitude of 30° above the horizon? (Answer: at a latitude of 54° and at $4\frac{3}{4}$ hours $= 71\frac{1}{4}°$ before noon.) We can in this problem establish two unknowns because we use both Menelaos theorems. I am not entirely satisfied with this interpretation. Toscanelli's use of the letter *z* suggests that this point should be at zenith, but I have been unable to devise such an arrangement. For the set of six numbers in section 4, then, we have:

$(n_1) = 113; 37, 54$	$ta = n_1 = 71; 15°$	$(n) = 120$	$ea = n = 90°$
$(r) = 120$	$tz = r = 90°$	$(r_2) = 109; 44, 53$	$zh = r_2 = 66; 8, 40'$
$(s_1) = 103; 55, 26$*	$hb = s_1 = 60°$	$(s) = 120$	$be = s = 90°$

* probably a mistake for, 23

Substituting these values in theorem I,

$$\frac{120}{113;\,37,\,54} = \frac{109;\,44,\,53}{120} \cdot \frac{120}{103;\,55,\,23}$$

or, decimally, 1.056 = 1.056, confirming the relation. For the second set of six numbers in this section:

$(n_2) = 38;\,34,\,22$	$et = n_2 = 18;\,45°$	$(n_1) = 113;\,37,\,54$	$ta = n_1 = 71;\,15°$
$(s_2) = 60$	$eh = s_2 = 30°$	$(s_1) = 103;\,55,\,23$	$hb = s_1 = 60°$
$(m_2) = 70;\,33$	$hz = m_2 = 36°$	$(m) = 120$	$za = m = 90°$

Substituting these values in theorem II,

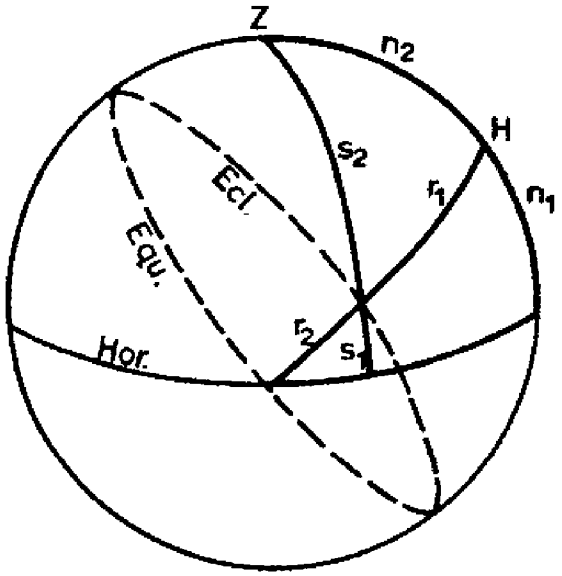
$$\frac{60}{103;\,55,\,23} = \frac{120}{70;\,33} \cdot \frac{38;\,34,\,22}{113;\,37,\,54}$$

or, decimally, 0.577 = 0.577, confirming the relation.

One quantity which does not appear directly is $r_1 = r - r_2$, which turns out to be 23; 51, 20, Ptolemy's value for the obliquity of the ecliptic. In section 7, discussed below, the chord of this is given as 48; 31, 55, precisely the value used by Ptolemy (*Almagest* I, 16). There were other values current for the obliquity of the ecliptic — — al-Battani had used 23; 35, Regiomontanus used 23; 28. Toscanelli's use of Ptolemy's value is good evidence that Toscanelli used the *Almagest*. The letter of Regiomontanus to Bianchini in February 1464 (Murr 1786: 148) refers to Toscanelli's determination of the obliquity of the ecliptic as 23; 30, but this page seems to be much earlier, evidently before Toscanelli derived the lower value.

Section 5 on this folio contains a decimal multiplication problem which is interesting because it represents the numerator of the application of theorem II, above, in numbers which have been rounded off. So it has $104 \times 38\frac{1}{2} = 4004$, then $4004 \times 120 = 480480$. These computations do not appear in sexagesimal form on this page; only the quantities which set up the problem are given.

Section 6 also contains an approximation to the same problem in Section 4. The six numbers in the lower part of that section are given here rounded to the nearest whole number: 39, 60, 71, and 114, 104, 120. The juxtaposition of these two approximations with the small eccentric diagram suggests some relationship between them, but it may be only a question of empty space on the paper.



Elsewhere on the page there are other sets of numbers which fit relations of the Menelaos type. Section 7 has two sets of six numbers each, not identified with any letters, with the addition of four extra numbers on the left: 180, 60, and 180, 120. The first set of six can be arranged in a Menelaos configuration as shown below, where again the letters m, n, r, s, are Neugebauer's. The problem can be stated: at a latitude of 30°, how far above the horizon is the sun at summer solstice at 6 a.m.?

$(r) = 120 \quad r = 90° \quad (r_2) = 48; 31, 55 \quad r_2 = 23; 51, 20°$

$(n_1) = 60 \quad n_1 = 30° \quad (n) = 120 \quad n = 90°$

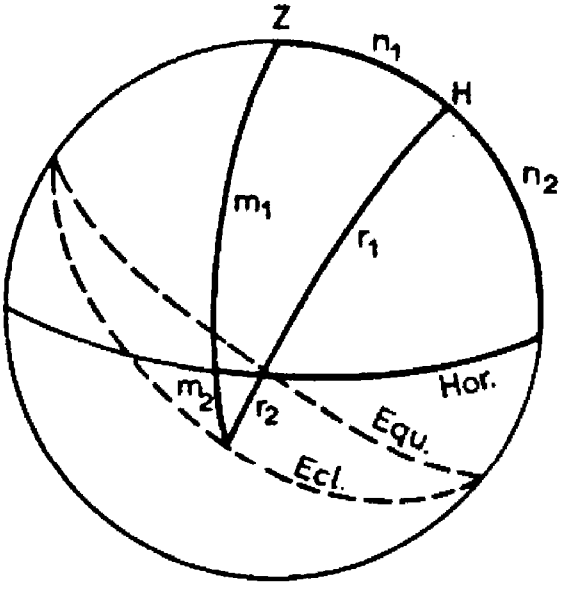
$(s) = 120 \quad s = 90° \quad (s_1) = 24; 15, 57 \quad s_1 = 11; 40°$

and, using theorem I,

$$\frac{120}{60} = \frac{48; 31, 55}{120} \cdot \frac{120}{24; 15, 57}$$

or, $2 = 2$, confirming the relation.

The second set of numbers in this section fits a similar problem, namely, at a latitude of 60°, how far below the horizon is the sun at winter solstice at 6 a.m.? This set of numbers can be arranged as follows:



$(r_1) = 120 \quad r_1 = 90° \quad (r_2) = 48; 31, 55 \quad r_2 = 23; 51, 20°$

$(n_2) = 103; 55, 23 \quad n_2 = 60° \quad (n) = 120 \quad n = 90°$

$(m_1) = 120 \quad m_1 = 90° \quad (m_2) = 42; 1, 48 \quad m_2 = 20; 30, 9°$

and, using theorem II:

$$\frac{48; 31, 55}{120} = \frac{42; 1, 48}{120} \cdot \frac{120}{103; 55, 23}$$

or, decimally, $1.547 = 1.547$, confirming the relation.

The numbers in Section 8, which I am not certain comprise a unit, are certainly suggestive of other sets of this kind, but I have not been able to make them work out. Some of these numbers appear elsewhere on the page, for example the 113; 37, 54 which is in section 1, and 103; 55, 23 and 48; 31, 55 at the top of section 9 next to the 120.

Section 9 contains numbers arranged as if in a list. No operation on them is indicated. As

just mentioned, several of the numbers are the chords used in the Menelaos configurations discussed above.

Section 10 is an addition problem as follows:

g	*m*	2	3	4	
48	31	55			(one of the chords from Section 7)
42	24	23			
	27	48	35		
	54	28	25		
		18	50	25	
			24	53	5
(8	15	19)	11	21	
(92	18	54)	26	39)	5
84	3	35	16	39	
42	1	48			(one of the chords from Section 7)

The quantities in parentheses have been crossed out. The sum 92, 18; 54, 26, 39, 5 is the correct sum of the column above, except for the 8, 15; 19. Subtracting from this sum the number 8, 15; 19, 10 gives the difference 84, 3, 35, 16, 39, 5 which is then divided in half to give 42, 1, 48 (rounded off) which is again one of the chords from Section 7. The other numbers in this section do not seem to be related; perhaps they are to be added or subtracted further, but this has not been done.

Section 11 is a small addition problem:

46		
15	2	
	11	44
61	13	44

The sum is correct. In the middle of the numbers appears the word *arcus*; this perhaps belongs to the number 23; 19, 59 to the left of it, in Section 8. Similarly, Section 12 is an addition problem:

48		
16	24	
	12	24
64	36	24

The sum is correct, and the numbers are all curiously multiples of four. Both these sums are located in the assorted numbers of Section 8, not set off in any way from the others. This seems to me to strengthen the assumption that some of this is just miscellaneous jottings, that it is not all necessarily related, though some of it certainly is.

Section 13 is also a small sum, with some extra numbers adjoined:

1	9	
	1	12
	15	20
125		16
	85	48
	39	40

Section 14 has another list of numbers and some numbers apparently in isolation.

Section 15 has a different character. As far as I can make it out, it is as follows:

	g		g	
baculus	45	corda	0 63	
	60		1 18	40 corda e quantum
	0,44 45		1 43	quantum corde
sino latitudinis	0 33 50	eius quantum	1 9	9 quantum corde
Iovis die veneris 13 novembris 1433			1,38	secunde

The edge of the page is badly eroded, the writing heavily abbreviated and very small. Celoria (1921: 6) transcribed part of it as "quanta corde descendente", but I cannot make it say that. It seems clear that part of this at least is an observation of Jupiter, 13 November 1433, taken with a baculus, or Jacobstaff. This is after the period in which he was making observations of the comet of 1433 (October 3–31). According to Tuckerman (1964: 734), Jupiter on 15 November 1433 was at longitude 140.75, latitude 0.82, which would make the latitude on 13 November about 0; 48, 36, not so very far off from Toscanelli's 0; 44, 45. But the chord of twice 0; 44, 45 is 1; 34, 15, not 1; 43 as one would expect from this little table. If the table is taken to mean that a baculus reading of 45 gives a chord of 0; 63, and of 60 gives 1; 18, 40, then a reading of 1; 44, 45 would give a chord of about 1; 43. This does not seem a likely interpretation of the table. If the first entry should be read as 0; 45 instead of 45; 0, then the values in the second column corresponding to 45 and 0; 44, 45 should be almost equal, which they are not.

Turning to fol. 245 v (see plate VII, p. 76), we find other numbers which Celoria (1921: 6) dismissed as "numeri diversi", but which also are suggestive that a less shallow interpretation should be possible. At the left is a table of explements, paired numbers whose sum is 360, in increments of 6, from 6 to 180. The table which occupies the top third of this page consists of five columns. The fourth and fifth columns are supplementary numbers, again in increments of 6 from 6 to 90, while the sum of the first four columns in each row is 360:

	ex secunda			a tota		
nota corda	144	120	90	erat numero quarta quod est	6	et ex quantitas 174
nota corda	144	108	90		18	162
nota	120	108	120		12	168
	108	108	120		24	156
	120	120	90		30	150
	*120	144	60		36	144
	*144	90	90		36	144
	120	120	72		48	132
	108	120	90		42	138
	**144	90	72		[54]	[126]
	108	108	90		54	126
	*120	120	60		60	120
	144	90	60		66	114
	*108	120	60		72	108
	120	90	72		78	102
	108	108	60		84	96
	* 90	90	90		90	90

* these rows have been cancelled, with a line drawn through them

** this row was squeezed in between the others

It looks as if Toscanelli started working from the left, then after doing a couple of rows and seeing that he had gotten them out of order (see the 6, 18, 12 in the fourth column with the order reversal indicated) jotted down the table of explements on the left, then proceeded, but

again reversed the order of the rows corresponding to 42 and 48 in column 4. I do not understand why he should have cancelled the five rows which have been crossed out. This may be a table to provide ease of access to a chord table. The verbal headings give some clues; they say, roughly, "the known chord [...] will be a number the fourth of which is [...] and from the quantity..." The heading says "from the second to the whole", and below the table there is "from the third", heading a small list of multiples of 0; 45, "from the fourth" heading the single number 2; 15 (= 3 × 0; 45), and "from the [fifth?]" next to 4; 30 (= 6 × 0; 45).

This page contains two other small groups of numbers which may or may not be related to this table or to the cometary observations in the center. At the top right-hand corner are the following:

g	*m*	2						
8	39	24		12	16	13	40	[130?]
		36		1	24	60		
							132	

The 8; 39, 24 is circled to set it apart. In the lower right, tucked in beside the comet diagram, are the following:

			ra	85	$\frac{1}{2}$			
				105				
				28	28			
	a.	36	15	0	35			
	b.	45		0	42			
1.28	a.	45		0	43	28		
	a.	60	0	57	56	30		
	b.	60		56				
				1	52	32	[?]	

These baffle me completely. They are not chords nor do they have chords which appear elsewhere, except that $85\frac{1}{2}$ is approximately the sum which appears at the lower left of fol. 245 r, Section 13.

Careful examination of this page of calculations, then, has revealed several things about Toscanelli. He was conversant with sexagesimal notation and computation but also used decimal notation and fractions. He used spherical trigonometry of a traditional kind, from Ptolemy, using the Menelaos theorems to solve astronomical problems. He used at this time precisely Ptolemy's value for the obliquity of the ecliptic though, as we have seen in chapter V, he was later to revise this value. He used a baculus or Jacobstaff for observing the position of Jupiter on 13 November 1433. And he constructed tables to help in access to tables of chords.

A number of questions have been left unanswered. Further study of these calculations will surely reveal other regularities and may explain more completely Toscanelli's mathematical and astronomical techniques.

Appendix C.

REGIOMONTANUS' SIXTEEN PROBLEMS, FACSIMILE

IOANNIS DE MONTEREGIO GERMANI, VIRI UNDECUNQUE DOCTISSIMI,
DE COMETE MAGNITUDINE, LONGITUDINEQUE AC DE LOCO EIUS VERO, PROBLEMATA XVI.

I reproduce here, with the kind permission of Yale University's Beineke Rare Book and Manuscript Library, the first edition of this treatise, published in Nuremberg, 1531, together with my translation of the editor's preface.

Johannes Schoner, Mathematician, extends many greetings to Erasmus Ebnerus, Patrician of Nuremberg.

This August we saw a comet; it was brilliant red-gold at the beginning of its appearance, but later it gradually waned day by day, and exhibited a more and more ragged coma. As I saw it, it did not bear with it very much fomentation by any means, nor did it foster fire exceedingly, though it was fiery enough. Neither was its progress long or horrible, but it withdrew by slow degrees from the west to the north and back again, towards evening it might be observed in its course in setting. You may have heard different, nay contradictory, judgements by the masses. This one affirmed pestilence abroad on the earth; that one pronounced sterility. There were those who inferred funerals of great princes; several, the destruction of cities; the remainder, devastation and the stirring up of war; others considered other possibilities. And yet I know not to fear the appearance of signs in the sky, even as Christ said. Nevertheless, I should have judged anyone who wishes to discern exactly the profundity of divine wisdom as not so much stupid as foolish. For mortal weakness will not be able to grasp the profundity of divine wisdom. Hereafter speaking of things which our God wishes us to know, Johannes of Monteregio, a truly divine man, has explained all things most perfectly in this little book of not more than sixteen problems. For anyone who wants to judge comets without error or deceit must know those things which this most learned man has most excellently pursued in an orderly way. For how can anyone publish anything certain who is ignorant of the comet's distance from earth? Or how will he not err who does not know how to measure the comet's distance from the earth's center and from the observer? Or how can you have any faith in one who is unable to compare the diameter of the comet's body with the earth's diameter under a sure proportion? Unless a person will observe diligently the comet's volume, the length of its tail, and the volume of its tail, I do not see why we should give him credence. It is agreeable indeed to publish all this under your name and to dedicate it as a gift to you, because you are a student of heavenly things and also because by this study I wish to declare my good feelings toward you. For in this your youth you have progressed so far in the mathematical discipline that not only your coevals but also your elders are seen to lag a long way behind you. Farewell. From Nuremberg, 12 Calends September, year of our deliverance 1531.

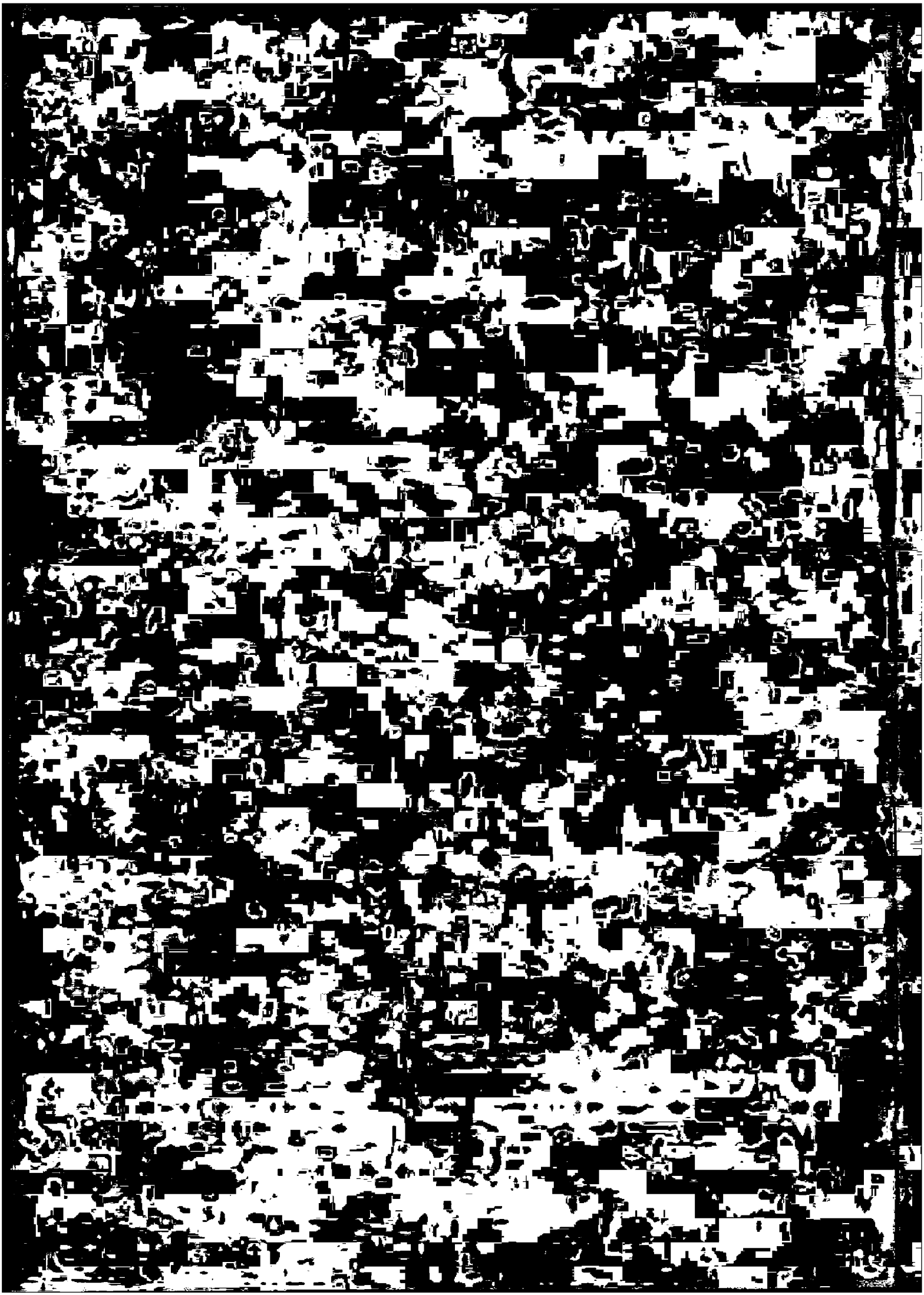
IOANNIS DE MONTEREGIO GERMANI, VIRI VNdecunq; doctissimi, de Cometæ magnitudine, longitudinecq; ac de loco eius uero, problemata XVI.

THOMAS VENATORIVS.

Qui uis horrendum cognoscere forte Cometen,
Illius & motus fare subinde feros.
Quid fumosa ferant spatioso incendia mundo,
Ducat ut è rutilo uertice, flamma, comam.
Ceteraq; in primis promittere sepe Cometes
Que solet, hoc modico conspicias aucta libro.

Cum gratia & priuilegio Cesareæ Maiestatis, ad decem Annos Io. Schonero concesso &c.

Norimbergæ apud Fridericum Peypus, Anno, D. M. XXXI.



IOANNES SCHONER MA-
thematicus, Erasmo Ebnero Patricio Norimbergensi, S.P.D.

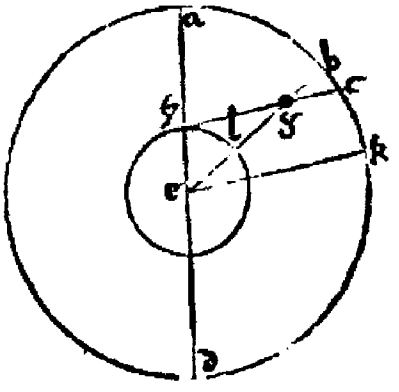
Vidimus hoc mense Augusto Cometen, rutilum quidē principio apparitionis suæ, sed qui postea paulatim in dies singulos deficeret, semperq; magis squalentem ostenderet comam. Haud multum fomenti secum ferre uisus est mihi: neq; item plurimum ignis conceperat, sed tamen flammeus satis; neq; tractu longus aut horribilis, sed qui ceu lento gradu ab occasu ad Arcton sese reciperet, donec rursus sub uesperum, secundo cursu in occasu conspiceretur. Audisses tum uaria, imo pugnantia iuditia uulgi. Hic aiebat minari terris pestilitatem, ille sterilitatem pronunctiabat. Erant qui magnorum funera regum interpretarentur, nōnulli excidia urbium, reliqui clades & belli motus, atq; alij alia cōmenti sunt. Ego & si sciam non temere apparere in cœlo signa, quemadmodum etiam dixit Christus, tamen qui uelit de diuinæ sapientiæ profunditate exacte discernere, illum ego non tam stultum q; stupidum esse reputauerim. Non enim diuinæ sapientiæ profunditatem, mortalis infirmitas capere poterit. Quæ porro hisce de rebus scire nos uoluit deus noster, ea oīa Ioannes de Monteregio, homo uere diuinus, in hoc libello non amplius q; XVI. problematibus absolutissime complexus est. Nam de Cometis iudicare ut non cuiuis est ita facile aut falli aut fallere poterit, cui icognita hæc manserint, quæ hic doctissimus homo pulcherrimo prosequutus est ordine. Quomodo enim aliquid certi pronunctiabit qui distantiā Cometæ a terra ignorauerit? Quomodo aūt non errabit, qui distantiam Cometæ a centro mundi, centroq; uisus humani metiri nescit? Aut quomodo fidem ei habere possis, qui diametrum corporis Cometæ, ad terræ

diametrum ſub proportione certa conferre nequiuerit? Corpulentiã Cometæ, longitudinemq; caudæ illius, groſſiciem quoq; caudæ niſi quis diligenter obſeruauerit, non uideo cur uere illi fidere debeamus. Placuit uero hęc oĩa ſub tuo nomine publicare, tibiq; muneri mittere, cum quia cœleſtium rerum ſtudioſus es, tum quia hoc ſtudio, meam in te beneuolentiam, alijs quoq; declarare uolui. Eo enim in hac tua iuuenili ætate progreſſus es, ut in Mathematicis diſciplinis, non modo coæuos tuos, ſed & natu quoſdam maiores, longo poſt te interuallo relinquere uideare. Vale Ex Norimberga XII. Calen. Septem. Anno ſalutis noſtræ. M.D.XXXI.

PROBLEMA Primum.

Distantiæ Cometæ a terra inuestigandæ præambula quædam accomodare.

Quoniam centrum oculi quidem considerantis distat, a centro mundi: centrũ aũt Cometæ ab utroq; eorũ remouetur, necesse est tres rectas memorata tria puncta iungentes semper concurrere ad angulos, nisi unum eorum quodlibet ex directo reliquorum duorum fuerit situm, id est, dum una & eadem recta linea, dicta tria puncta complectitur. quod quidem euenit Cometa supra uerticem capitum constituto, cum etiam idem est locus uerus Comete in cœlo & locus uisus, alibi enim Cometa existente semper hæc duo loca discrepant, atq; eo amplius quo Cometa ipse a summitate capitum remotior inuenietur. Locum autẽ uerum Cometæ a uertice capitũ declinantis, uiciniorem esse ipsi uertici capitum q̃ locum uisum facile doceberis, si prius a centro mundi centroq; uisus duas rectas eduxeris lineas in centro Cometæ confluentes, easq; ultra porrexeris, donec ad duo puncta primi mobilis desinant, nam quæ a centro mundi egreditur & si priusq; Cometam offendat inferior sit reliqua de centro uisus exeunte, tamen ultra Cometam euadentes eas mutatis intelliges uicibus. Quæ res picturæ officio comodius lucubrabitur.



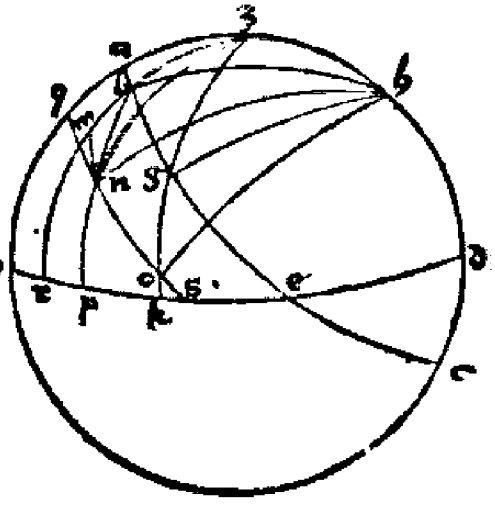
Sit cirulus a, b, c, d, uice orbis magni, cuius respectu moles terræ insensibilis accipitur, super cẽtroq; eius quod sit e, circulus maximus in' sphæra terræ describatur, duobus caracteribus, h & l, representandus, sitq; h, tãq; centrum uisus in superficie terræ, extensa demum, e, h, semidiametro terrę utrinq; donec occurret circũferentiæ circuli a, b, c, d, in duobus

punctis.a.quidē ſublimiori,d.autem humiliori,erit.a.punctus uertici capitis ſuprapoſitus, ſtatuaturq; centrum Cometæ extra diametrum.a.d. in puncto.g. & ducantur duæ rectæ a notis.e.&.h.per ipſum.g.punctum occurſuræ ambitui circuli memorati in punctis.b.&.c.erit itaq;.b.locus uerus Cometæ ꝓpinquior puncto.a.q̄.c. locus uiſus eiuſdem.Quod ſi ſtatuiſſemus Cometam in.a.d. diametro,nemini dubium uideretur locū uerū eius a locoviſo non differre.Ceterum ſi educatur ſemidiameter.e.k. æquediſtans lineæ.h.g.punctus.k.inſenſibiliter a puncto.e. remouebitur,q̄ totam terram apud orbem.a.b.c.d.puncti uicem obtinere ſubiectum ſit, quemadmodum Ptholemæus etiam in quinto magnæ compilationis ſuæ circa diuerſitatem aſpectus lunæ raciocinatus eſt, unde non iniuria duorum punctorum.e. &. k. alterum pro altero ſumere licebit. & q̄uis centrum Cometæ punctum. c. præoccupet oculo in h.exiſtenti,non tamen niſi punctus.k.conſideratori per instrumentum innoteſcit,nam angulus.a.h.c.inſtrumenti officio deprehenſus,æquatur angulo. a. e.k. cuius cū uertex in cētro circuli.a.b.c.d.quieſcat,eius ad quatuor rectos ꝓportio cognita,ipſius arcus reſpectu, totius circūferentiæ rationem latere non ſinet. Eſt autem punctus.a.poſitione datus,quamobrem & punctus.k.poſitionem habebit notam, punctum autē.c.q̄uis angulus.a.h.c. conſtet, nemo ſcrutabitur niſi prius ſemidiametri terrę e.h.ad ſemidiametrum.e.a.proportionem didicerit.Siue igitur punctum.c. appellatione loci uiſi,ſiue punctū. k. accipias, nihil intererit quod a propoſito conſequendo nos arceat,non enim naturæ theſauros prorſus euacuare, ſed in pleriſq; ſcibilibus ipſi ueritati propinquū deguſtare mortalibus concedi tur.Similiter &ſi arcus.b.c. diuerſitas aſpectus Cometæ diffiniatur,q̄ eius uerum atq; uiſum intercipiat locum,arcus tamen. b.k.eodem uocabulo diuerſitatis aſpectus nominari merebitur,cum & inſenſibiliter ab ipſo arcu b.c.

differat,& propoſiti attingendi facultatem nobis trſbuat, ueluti inferius explanabitur. Nunc quo pacto memorata diuerſitas aſpectus Cometæ inquirenda ſit operepreciũ differemus,qua quidem neglecta,neq; interuallum Cometæ & centri mundi,neq; eorpulentiam eius,aut alia huiuſmodi metiri licebit.

PROBLEMA Secundum.
Diuerſitatem aſpectus Cometæ in circulo altitudinis percontari.

Conſiderandæ ſunt in primis duæ altitudines eius q̃ diligentiſſimũ cũ azimuth ſuis,ambæ uidelicet aut ante meridianę,aut poſtmeridianę,Quibus deprehẽſis hac gradiemur via.Sit cirulus meridianus a.b.c.d ſub quo medietas horizontis orientalis ꝑ libito b.e.d.Cometa ſecundũ veritatem quidẽ intelligat̃ in.g.puncto,demiſſoq; a polo horizontis ,z. quadrante z.k. per locũ verũ Cometæ in cœlo, ſignet̃ in eo locus viſus Cometę ꝑ notam o. oportet eñ ſemper in eodem circulo altitudinis vtrunq; locũ & verũ ſcilicet & viſum reperiri,arcus ſemidiurnus Cometæ verus ſit.a .e,& arcus ſemidiurnus pũcti.o.ſit q.s.A polo denicq; mũdi.h.boreali ducantur duo arcus circulorũ magnorum h.g,& h.o.Hæc quidẽ circa primam conſiderationem,In ſecunda autẽ conſideratione locum verũ Cometæ nota l,repreſentet, per quam ex polo horizontis z.deſcendat quadrans ciruli magni z.l.r, ductoq; arcu circuli magni h. l,qui erit æqualis arcui h.g,conſtituatur



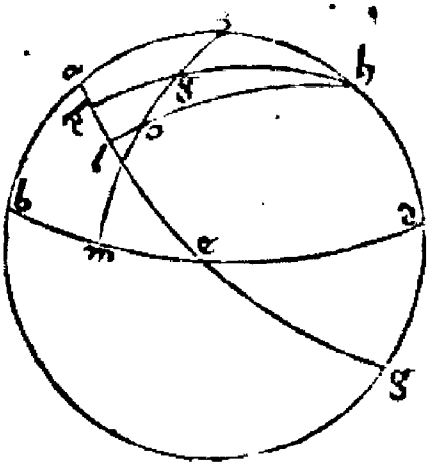
angulus.l. h.n. æqualis angulo.g.h.o. ducendo etiam arcum.h.n. æqualem ipſi. h. o. arcui, palam itaq; quot ſicut in medio tempore duarum conſiderationũ punctus g. primi mobilis ad ſitum l,ita punctus o. ad notã n. traducitur cũ duo quidẽ anguli.g.h.l.&.o.h.n.æquales ſint inuicem. Cometam autem non niſi ad motum primi mobilis in tantulo tempore moueri imaginemur, demiſſo igitur a polo horizontis quadrante magno z.p.per ipſum punctum.n. ſignetur locus viſus Cometæ in ſecunda conſideratione puncto.m, ac tandem adiungantur duo arcus circulorum magnorum l.n,& m.n.Iam ad argumentationem deſcendemus. Per cõſiderationem primã cognoſcitur arcus.z.o. diſtantia ſcilicet loci viſi a ſummitate capitum,inuenitur etiam angulus.b.z.k, eſt autem.z.h.cõplementum latitudinis regionis notum. Triangulus itaq;.z.o.h.duo latera habet cognita cum vno angulo,quamobrem arcus h.o innoteſcet cũ angulo.z.h.o, qui eſt diſtantia puncti. o. a meridiano,angulus quoq;.h.o.z.nõ ignorabitur.Cum autem tempus medium inter duas conſiderationes ſit cognoſcibile,erit angulus. g.h. l. notus & ei æqualis.n.h.o,reliquus ergo angulus. z.h.n. haudquaq; latebit. Vterq; aũt arcuũ z.h.&. h.n.notus exiſtit,quare & arcus.z.n.innoteſcet cũ angulis.z.n.h.&.n.z.h. Item per cõſiderationẽ ſecundam arcus. z. m.addiſcitur cũ angulo.b.z.r, dempto igitur angulo. b.z.r.ex angulo.b.z.p.noto propter angulũ.n.z.h, relinquetur angulus.m.z.n.cognitus,cumq; duo arcus.z. m.&.z.n.ſint noti,erit et arcus. m .n. cognitus cũ duobus angulis.z.m.n.&.z.n.m.Duo aũt trianguli.l.h.n,&.g.h.o ſunt æquilateri & æquianguli,& erat angulus.g.o.h. pridem cognitus,cui æqualis eſt.l.n.h. Itẽ angulus.z.n.h.notus declarabatur,totus ergo angulus m.n.h.ex duobus notis conflatus innoteſcet, ex quo ſi dempſeris angulũ.l.n.h. relinquetur angulus.l.n.m.notus. Triangulus itaq;.l.m.n. latus.m.n.habet menſuratum cũ duobus angulis.l.m.n.et

l.n.m.

l.n.m,unde vterq; duorũ arcuum l.m.& l.n.notus conuincitur. eſt autẽ arcus l. n æqualis arcui g.o,qui erat diuerſitas aſpectus Cometæ in prima conſideratione,arcus autẽ l.m.eſt diuerſitas aſpectus Cometæ in ſecunda conſideratione,quarum gratia hucuſq; fatigati ſumus. Hæc autem omnia quemadmodum ſupra monuimus, ſupponũt Cometam in tempore medio duarum conſiderationum non moueri niſi ad motum primi mobilis, qui &ſi interea moueatur,in tempore tamen adeo breui haud multum ſenſibilis erit motus eius proprius.Longe aũt inſenſibilius variabitur arcus h.g.diſtantia videlicet Cometæ a polo mundi ſecundum veritatem.

PROBLEMA Tertium.
Aliter idem abſoluere.

Notanda eſt altitudo Cometæ antemeridiana vel poſtmeridiana cũ arcu azimuth eius, inſtanſq; huiuſmodi obſeruationis animaduertendum eſt, ſed & inſtans quo Cometa ipſe meridianum poſſidet non eſt negligendũ, quod facile fiet per obſeruationem cuiuſpiam ſtellæ fixæ locũ notum habentis,erit itaq; tempus medium inter duas conſiderationes notum. Sit itaq; nunc meridianus circulus a.b.g.d,ſub quo dimidius horizon orientalis b.e.d,& medietas æquatoris a.e.c. Cometa autẽ in obſeruatione antemeridiana puncto g.ſignificetur ſecundum veritatem, demiſſoq; ex polo horizontis z.quadrãte magno z. m. per punctũ g. ſignetur in eo locus viſus Cometę pũcto o. polus deniq; mũdi h.borealis initium eſto cõmune duorũ quadrantũ magnorũ h. k.& h.l.per duo puncta g.& o, tranſeuntium. Cum itaq;



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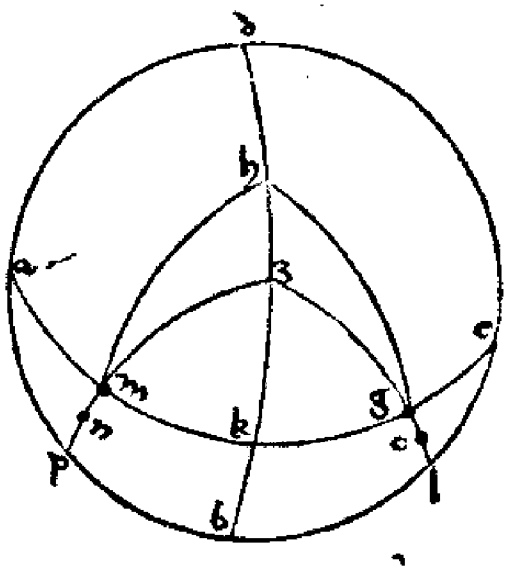
tempus duas memoratas cõsiderationes complectens sit notum, erit angulus g.h.z cognitus, propter azimuth autẽ notũ, angulus quoq; g.z.h. cognoscẽt, arcus insuper.z.h qui est cõplementũ latitudinis regionis, nõ ignorabit. Triangulus itaq; g.h.z. latus vnũ z. h notum habens cũ duabus angulis suis, latus aliud g.z mensurandum præbebit, arcum autẽ o.z instrumenti officio didicisse oportuit, quippe qui distantiam Cometæ visam a vertice capitum complectitur, quamobrem reliquus arcus g.o non latebit, qui est diuersitas aspectus Cometæ in circulo altitudinis. Non aliter ratiocinandum foret si consideratione postmeridiana vteremur. Quod si motum Cometæ proprium in tempore medio duarum considerationum aliquid erroris ingerere suspiceris, hac lege animo satisfacies tuo. Motum proprium Cometæ in vno die naturali deprehendas: hinc pro tempore medio duarum considerationum quantus sit eius motus proprius addiscas: cui denicq; quantũ de æquatore respondeat, facile scrutaberis, et secundum eius quantitatem angulum g.h.z. vel maiorem vel minorem, si res ipsa postulat, constitues. Motum autẽ Cometæ proprium in die naturali prope verum hac habebis via. Considera verum locũ Cometæ initio apparitionis suæ, verumq; locum eius in fine apparitionis, & spatiũ a Cometa pertransitum in numerum dierum mediorum distribue, habebis enim ferme motum Cometæ diurnum, quem petebas.

PROBLEMA Quartum.
Quod præcedentes tradiderunt, alijs argumentis concludere.

Cometa nonnunq; meridianum occupat sole supra horizontem existente, ac quo minus oculo deprehẽdatur, efficiente, si tamen & ante solis ortum & post eius occasum

videatur, tametſi meridianum haudquaq; obtineat, hiſce fruemur rationibus. Conſiderabimus duas altitudines Cometæ antemeridianam ſcilicet & poſtmeridianam æquales cum gradibus azimuth: deinde figurationi incumbemus in qua circulus horizontis ſit a.b.c.d, ſupra quem dimidius meridianus d.z.b, arcus diurnus Cometæ quem videlicet raptu primi mobilis deſcribit, eſto e.k.a. intelligaturq; Cometæ locus verus prius quidem in g. puncto antemeridiano, deinceps autem in puncto m. poſtmeridiano, demiſſiſq; ex polo horizontis z. duobus quadrantibus magnis z.l. & z.k. per duo puncta g. & m. Fingamus punctũ o. locum viſum Cometæ antemeridianum, punctum vero n. item locum viſum eius poſtmeridianum, duobus arcubus o.l. & n.k. æqualibus exiſtẽtibus, veluti ſuperius monebatur, quo demum euenire neceſſe eſt, vt duo quoq; arcus g.l. & m.k. æquales inuicem reperiantur, neq; ob eam conditionem duorũ arcuum g.k. & k.m. alter alterum excedere poterit. Quod ſi a polo mundi h. boreali ad duas notas g. & m. duos arcus circulorum magnorum produxeris, æquales eos eſſe doctus conſitebitur geometra. Iam quoq; tempus medium duarum conſiderationum nouiſſe oportebit, id autẽ patrocinio ſtellę fixę cuiuſlibet notæ nõ erit difficile percontari, quo cognito et arcus g.m. et angulus g.z.m. noti proſilient: hinc etiam angulus g.h.k. ſine g.h.z. innoteſcet, q vterq; eorũ ſit medietas anguli g.z.m. Angulum preterea g.z.k. inſtrumenti officio, quemadmodum in pręcedentibus cõprehendi oportet, cuius quidem magnitudinẽ determinat arcus azimuth. atq; idcir-



co reliquus de duobus rectis, angulus ſcilicet g. z. h, non ignorabitur, cumq; arcus z.h, ſit complementum altitudinis poli ſeptentrionalis, habebit triangulus g. z. h. duos angulos g.z.h.& g.h.z.notos cum latere h.z.quare vterq; arcuum h.g.& z.g.notus emerget. Erat autem & arcus z.o. notus per obſeruationem, idcirco reſiduus g. o. non ignorabitur,qui eſt diuerſitas aſpectus Cometæ in circulo altitudinis queſita. Sed hic iterum ſupponitur Cometam in tempore medio duarum conſiderationum non moueri ſenſibiliter motu proprio. Si igitur propter motum eius proprium negotiũ hoc cupis reddere accuratius,fac quiem admodum in præcedenti monuimus. Cæterum ex hoc proceſſu conſtabit etiam declinatio vera Cometæ ab æquatore,Nã arcus h.g.eſt complementum huiuceſmodi declinationis,propter angulum autem g.h.k.notum cum inſtanti ipſo conſiderationis,notus elicietur punctus eclipticæ cũ quo Cometa ipſe cœlum mediat, vnde etiam locus verus Cometæ in ecliptica cum eius latitudine deprometur.

PROBLEMA Quintum.
Locum verum Cometæ in ecliptica inſtrumenti adiutorio cognoſcere.

Conſidera Cometam quando a puncto orientis diſtat ſecundum longitudinem eclipticæ per quartam circũferentiæ partem, tunc etenim locus eius verus a viſo loco non differet,quocirca loco eius viſo per inſtrumentum armillarum, aut aliud eiuſmodi comprehenſo, locus quoq; verus habebitur. Cum autem difficile ſit explorare ſitũ Cometæ huiuſmodi, animaduertendum cenſeo,tantam eſſe diſtantiam inter nonageſimum gradum ab aſcendente & meridianum ſecundum diuiſiones horizontis, quanta eſt amplitudo ortus aſcendentis, quod ſi geometricę demon-

ſtratum deſideres, alio concedendum eſt. Obſeruabis igi-
tur quando diſtantia Cometæ a meridiano ſecundum gra-
dus horizontis æqualis erit amplitudini ortus aſcenden-
tis, tunc enim aptato inſtrumento per ſtellam quamuis no-
tam conſtabit locus verus Cometæ, qui quęrebatur.

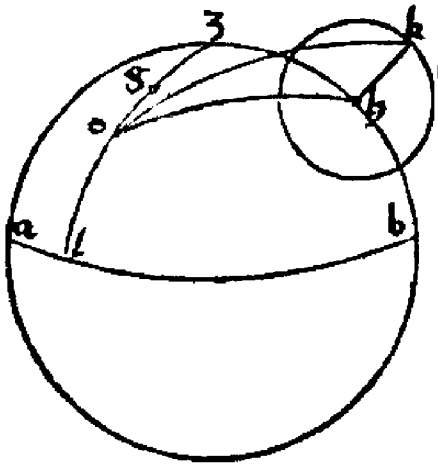
PROBLEMA Sextum.
Diuerſitatem aſpectus Cometæ in longitudine dirigere.

Ex præcedenti habes locum verum Cometæ, conſidera
itaq; Cometam alibi & in nonageſimo gradu ab aſcenden-
te exiſtentem, inſtrumentum enim dabit locum eius viſum
Sic ergo interualluin duorũ locorum, veri ſcilicet & viſi
innoteſcet, quod vocant diuerſitatem aſpectus in longitu-
dine. Quod ſi Cometa ſenſibiliter motus videretur motu
proprio in tempore medio duarum conſiderationum, me-
miniſſe oportebit eorum quæ ſupra monuimus. Nam per
motum Cometæ proprium tempori medio duarum con-
ſiderationum debitum, locus eius verus ſiue per additio-
nem, ſiue per ſubtractionem in altera ſcietur conſidera-
tione.

PROBLEMA Septimum.
Latitudinem Cometæ viſam ſi quam habeat explorare.

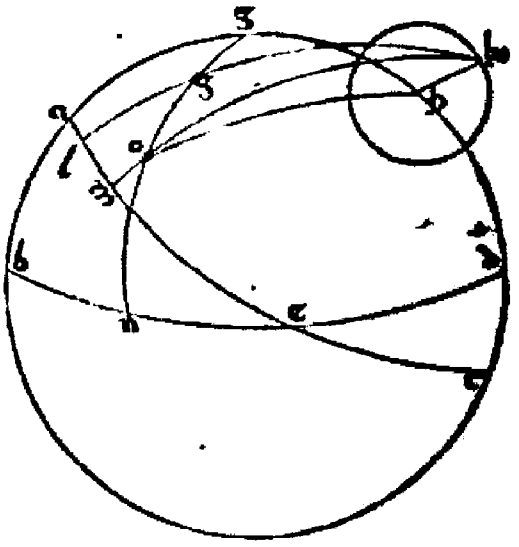
Ordinato inſtrumento per aliquam ſtellam fixam, vt
aſſolet, facile cognoſces latitudinem eius queſitam, ſi pre-
ceptis Ptholemei circa obſeruationes lunares, ſatis inuigi
laueris. Si tamen obſeruatione ſimpliciori id libeat conſe-
qui, conſidera diſtantiam viſam Cometæ a ſummitate ca-
pitum cũ gradibus azimuth: altitudinemq; cuiuſpiã ſtel-

læ fixæ notæ quatenus inſtans conſiderationis pateat. Deſcripto igitur circulo meridiano a. b. h. z. & ſub eo horizonte orientali dimidio a. l. b. locus viſus Cometæ ſit o. punctus, per quem deſcendat ex polo z. horizontis quadrans z. l. polus mundi ſeptentrionalis ſit h. circa quẽ circulus arcticus lineetur, & in eius circũferentia ſignetur polus eclipticę k. ducanturq; tres arcus o. k. o. h. & h. k. Ex arcu igitur z. o. per obſeruationem cognito cum angulo o. z. h. et z. h. complemento altitudinis poli notus erit arcus o. h. qui eſt complementum declinationis viſæ ipſius Cometæ, angulus etiam z. h. o. innoteſcet, propter inſtans autem conſiderationis notum conſtabit punctus eclipticę in meridiano exiſtens, cumq; arcus h. k. prolongatus ad partem k. tranſeat per principium capricorni nota erit aſcenſio recta reſpondens arcui eclipticæ inter principium capricorni & medium cœli intercepto. Hæc autem aſcenſio recta determinat angulum z. h. k. ipſumq; notificat, quo ſociato ad angulum z. h. o. totus angulus o. h. k. cognitus veniet. Eſt autẽ arcus h. k. æqualis maximæ declinationi ſolis, & arcus o. h. pridem erat cognitus, quare & arcus o. k. non ignorabitur, cuius complementum eſt latitudo viſa Cometæ quam quęſiuimus. Cognoſcetur inſuper angulus h. k. o. cui reſpondet diſtantia loci viſi ipſius Cometæ in ecliptica a principio cancri, quare tandem locus viſus Cometæ in ecliptica, non latebit. Quamuis autẽ polus eclipticæ k. diuerſimode ſituari poſſit in circumferentia circuli ſui, non tamen difficilior ex hoc reddetur inuentio anguli o. h. k. nonnunq; enim oportebit angulum z. h. k. demi ex angulo o. h. z. vt angulus o. h. k. relinquatur cognitus: in præſenti tamen figuratione duos prædictos angulos coniungi oportuit.



PROBLEMA Octauum.
Diuersitatem aspectus Cometæ in circulo altitudinis aliter q̃ superius inuestigare.

Huius gratia pingatur circulus meridianus a.b.g.d,sub quo dimidius horizon orientalis b.e.d.& medietas ecliptic æ a.e.c. Verus locus Cometæ sit g. visus autem o,amboq; hęc loca sint in quadrante z.n.a polo horizontis z.descendente. Polus mundi septentrionalis sit h, circa eũ circulus arcticus, & in eius circumferentia punctus k, polum ecliptic æ borealem repręsentet, a quo per duo puncta g.& o. duo quadrantes magni k.l.et k.m. incedant ad ecliptic am terminati. Erit itaq; l. locus verus Cometæ in ecliptica,m. autem locus visus,atq; idcirco arcus l.m. qui est diuersitas aspectus Cometæ in longitudine ex supra memoratis cognoscet Is arcus l.m. determinat quantitatem anguli g.o.k,quare et ipse angulus notus. Ducto insuper arcu h.o.& cognito per obseruationem arcu z.o,q est distantia visi loci cometæ a summitate capitum: itemq; angulo o.z.h,noto per instrumentum, erit vterq; angulorum z.o.h. & z.h.o.cognitus cum arcu h.o,hinc ex triangulo o. h. k. propter duo latera o.h. & h. k. cognita cum angulo o. h.k. quemadmodum in prȩcedenti angulus h. o. k. innotescet cum arcu o.k. scilicet cõplemento latitudinis uise. Demendo igitur angulum h.o.k.ex angulo z.o.h.relinquetur angulus g.o.k,notus. Erat autẽ prius angulus g. k.o. cognitus. Habebit ergo triangulus g. o. k. duos angulos notos

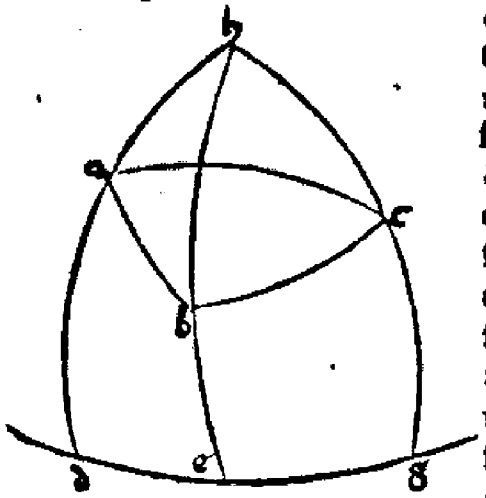


eum latere o,k,vnde & arcus g,o,non latebit,qui eſt diuerſitas aſpectus Cometæ in circulo altitudinis quæſita. Ex hac demum diſpoſitione cognoſcetur arcus g,k,& ideo etiam arcus g,l, latitudo ſcilicet Cometæ vera ab ecliptica. Illud quidem ſtante figura præſenti:nam ſi arcus g,k,quadrans inueniretur certum eſſet Cometæ locum verum in ecliptica abſq; latitudine comprehendi.

PROBLEMA Nonum.

Locum Cometæ viſum ſubtiliter agnoſcere.

Conſiderandæ ſunt duæ ſtellæ fixæ prope Cometam,et diſtantia viſi loci Cometæ ab vtraq; earum deprehendenda,deinde ad figuram veniendum in qua altera duarum ſtellarum conſideratarum ſit a, reliqua vero b, portio ecliptícæ in qua ſunt loca ipſarum ſtellarum ſit d,g,cuius polus h,ex quo duo quadrantes magni h,d,et h,e, deſcendant per puncta a, & b,Locus viſus Cometæ ſit in c, puncto,per quem demittatur quarta circuli magni ex polo eclipticæ,



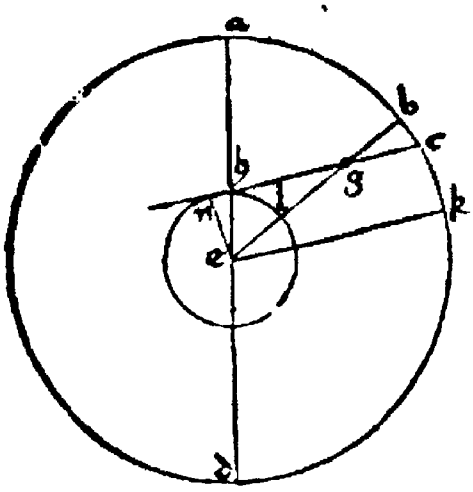
quæ ſit h,g,erit itaq; g, locus viſus Cometæ in ecliptica quem quærimus,& arcus g,e, latitudo eius viſa,ductiſq; tribus arcubus,a,b a,c, & b,c, magnorum circulorũ ,cum duæ ſtellæ a,& b,loca nota habere ſupponantur in ecliptica, cum latitudinibus cognitis,erit arcus d,e, ſcitus,qui determinat quantitatem anguli d,h, e,ſiue a, h, b, Duæ demum latitudines a, d, & b,e, notæ ſua complementa ſcilicet duos arcus a,h,& b,h,notificabunt,quare et ianguli a,h, b,duo latera a, h, & h,b,

h.b.nota habentis cum angulo a. h.b, latus quoq; a. b.cognitum accipietur, distantia videlicet duarum stellarum. Angulus etiam b. a. h. non ignorabitur. Deinde cum duo arcus a.c. & b. c. per considerationem sint deprehensi, arcus autem a.b. per argumentationem innotuerit, habebit triangulus a. b. c. tria latera cognita, & ideo angulus eius b.a.c. non latebit: quem si dempseris ex angulo b.a.h. priodem noto, relinquetur angulus h.a. c. mensuratus. Triangulus itaq; h.a. c. duo latera h.a. & a.c. nota habens cum ngulo h.a.c. angulum suum a.h. c. notum reddet cum ar h.c. Anguli autem h.a.c. quantitatem determinat arcus d.g. quare & ipse notus. Erat autem punctus d. cognitus, vnde & punctus g. latere non poterit. Sic locum Cometæ visum secundū longitudinem ecliptice notum effecimus. Arcus autem c.g. latitudinis scilicet viſę notus declarabitur propter complementū suum h.c. superius cognitum. Tandem igitur & locum Cometæ visum & latitudinem eius visam manifestauim⁹, quod libuit emoliri. Potest aūt huiusce modi negotij figuratio diuersimoda incidere, non tamen argumentatio multū variabitur. Libellusq; noster triangulorū sphęralium qualemcumq; sese figuratio prebuerit, ad metam te traducet optatam.

PROBLEMA Decimum.
Distantiam Cometæ a centro mundi, centroq; visus dimetiri.

Circulus altitudinis a.b.c.d. super centro e. constitutus, representet orbem magnum cuius respectu terra puncti vicem habere dicitur. Circulus h.l. terræ seruiat, diameter a.d. per punctum a. vertici capitis suprapositum, & h. centrum visus, quod est tanq; in conuexo terrę, incedat. Sit g. centrum Cometę: eductisq; lineis duabus per centrum Co

metæ,e.b.quidem a centro mundi,h,e,autem ex centro vi-
ſus,donec occurrant orbi magno ſupra memorato in pun-
ctis b,& c,Iam conſtat b.quidem eſſe locum verum Come
tæ,e,autem locũ viſum, vnde & arcus b,c, diuerſitas aſpe-



ctus Cometæ in circulo altitudinis diffinietur,ſi denicꝫ ex centro mun di egrediatur e,k, æquediſtans ipſi h,c,punctus k, inſenſibiliter diffe-ret a puncto c, quemadmodum in primo problemate explanauimus Quærimus igitur duas lineas e,g, & h,g,quarum altera quidem e,g, diſtantiam Cometæ a centro mun-di ſignificat,Altera uero h,g,remo tionem eius a centro viſus denotat Quærimus inquam ſecundum ali quam menſuram,ſiue famoſam ſi-ue notam:utpote reſpectu ſemidiametri terræ quam repre ſentat linea e,h,quod pulcre conſequemur, vbi lineam g, h,prolongauerimus,donec e,n,recta ex centro mundi ve-niens perpendiculariter ei poſſit inſiſtere,Erit enim per ob ſeruationem angulus a,h,g,& ideo ei contrapoſitus e,h,n, cognitus,cum punctus h,tanꝫ centrum inſtrumenti habea tur,In triangulo iraqꝫ e,h,n,rectangulo ꝓportio lineæ h,e, ad vtranꝫ rectarum e, n, & n, h, nota reddetur,ſed & per argumentationem multiplicem ſupra expreſſam arcum b, k,metiemur,qui & angulũ b,e,k, & idcirco ei coalternum e,g,n,notificabit,In triangulo igitur g, e, n, proportio g,e, ad vtranꝫ rectarum e, n, & n,g,nota proſiliet, Cum iraqꝫ vtriuſqꝫ duarum linearum g,e,& e,h,ad perpendicularem e,n,proportio ſit cognita, earum inter ſe quoꝫ non latebit proportio,Sic diſtantia Cometæ a centro mundi patefacta eſt,Erat autem proportio g, e,ad g,n,nota, vnde & n,g,re-ſpectu h,e,nota fiet,cuius etiam reſpectu pridem notifica-

uimus lineam n.h. Duæ ergo lineæ g. n, & n.h. ad lineam e.h. notis referentur proportionibus, quarum alteram minorem ſcilicet n.h. ex altera tota n.g. ſi reiecerimus, manebit linea h.g. diſtantia Cometæ a centro viſus reſpectu lineę e.h. cognita, quod libuit addiſcere.

PROBLEMA Vndecimum.

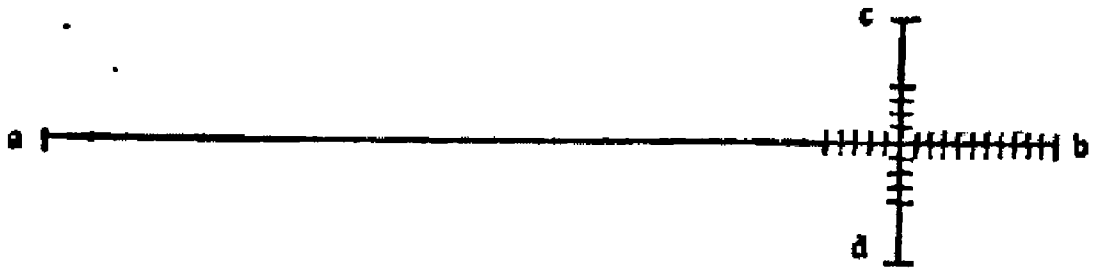
Quot miliaria centro Cometæ centroq; mundi vel centro viſus interiaccant faciliter edocere.

Quicquid de miliaribus dicitur ad aliam etiam quãcunq; menſuram ſiue vſitatam ſiue pro libito aſſumptã enunciare licebit. Semidiametrum tamen terræ prius cognitam eſſe oportet per eandem menſuram. Id autem quo pacto fiat, neminem latere arbitror. Quis enim ex ambitu terræ per quamcunq; menſuram noto, ſemidiametrum eius metiri neſciet? cognita igitur ſemidiametro terræ in miliaribus, Verbigratia, cum ex premiſſa didicerimus proportionem eiuſdem ſemidiametri ad vtranq; predictarum diſtantiarum, nota habebitur vtraq; earum in miliaribus. Eſt enim numerus miliarium quæ complectitur linea e.h. ad numerum miliarium quæ in linea e.g. reperiuntur, tanq; numerus menſuræ cuiuſcunq; in linea e.h. computatę ad numerum eiuſdem menſuræ quem linea e.g. aſſumit. Tres itaq; tales numeri noti quartum notificabunt proportionalem qui quærebatur.

PROBLEMA Duodecimum.

Diametrum Cometæ viſualem inſtrumenti artificio deprehendere.

Aptabiis regulam ſubtilem longitudinis quinq; aut ſex vel plurium cubitorum, quam diuides in partes æquales quotlibet, quo tamen plures eo laudabilius erit opus. Hanc repreſentare volumus per lineam a. b, cui aliam eo aptabiis regulellam c.d. ad angulos rectos, ita vt duo eius brachia vtrinq; ſint æqualia. Hæc regulella mobilis ſit ſu-

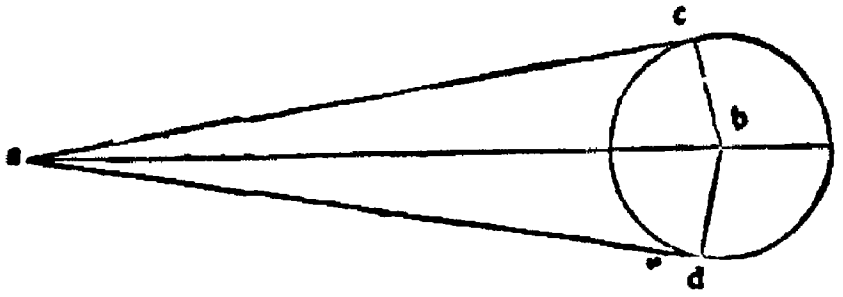


pra regulam a.b, in motuq; ſuo ſemper angulos rectos cũ ipſa regula a. b. contineat, cuius diuiſiones ſint quales in regula a.b. prę ſignauimus. In tribus deniq; punctis a. c. & d. tres clauiculi, ſubtiles aut acus infigantur. Sicq; abſolutum habebis iuſtrumentum, quo vteris hoc pacto. Pone punctum a. prope oculum tuum dextrum clauſo ſiniſtro, & regulam a. b. dirigas ad centrum Cometæ, quod comode fiet, ſi ipſi ſedem aliquam ſubſtituas, qua ſic manente, moue regulellam c.d. hinc atq; inde, donec ipſa occupabit totam diametrum Cometæ. Quo facto numerum particularum, quæ ſunt inter a. punctum, & c.d. regulellam mitte in tabulam huic negotio accomodatam, & ex directo eius numeri reperies diametrum Cometæ viſualem. Hanc autem tabulam alibi componendam trademus. Tali aut alio ſimili inſtrumento vti poteris non modo ad diametrum Cometæ menſurandam, ſed & Lunæ & Solis, modo lumen eius oculum non abſterreat.

PROBLEMA Decimumtertium.

Diametrum corporis Cometæ ad terræ ſemidiametrum ſub proportione certa conferre.

Corpus Cometæ in hac inquiſitione tanq; ſphęricum ſupponimus, cuius circulus maior ſit c.d. ſuper centro b. lineatus: centrum viſus a, cum centro circuli c.d. continuetur per lineam a.b. Ducantur demum duæ rectæ a.c. & a.d circulum c.d. contingentes in duobus punctis c. & d. duas ſemidiametros b.c. & b.d. terminantibus. Conſtat itaq; Cometam ipſum videri ſub angulo c. a. d, & ideo arcum qui



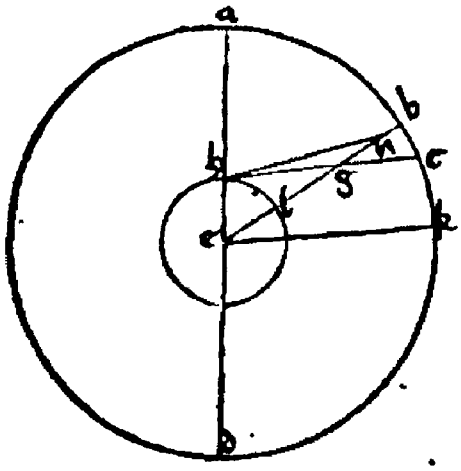
ſubtendit angulum c.a.d. eſſe diametrum viſualem ipſius Comete, quæ cum ſit nota per premiſſam, erit & angulus c.a.d. & ideo dimidius b.a.c. cognitus, quamobrem angulo apud c. recto exiſtente proportio a. b. ad b.c. ſemidiametrũ Cometæ cognita veniet, ſed ex ſupramemoratis erat a. b. nota reſpectu ſemidiametri terrę, quare b.c. eodẽ reſpectu non erit ignota. Per quãcunq; igit̃ menſurã terræ ſemidiameter nota conſtituetur, per eandẽ & ſemidiameter Cometæ atq; idcirco tota ſua diameter nõ ignorabitur, quam in hoc problemate ſcrutari inſtituimus.

PROBLEMA Decimumquartum.
Corpulentiam Cometæ tandem dimetiri.

Ex premiſſa conſtabat proportio diametrorum terræ & Cometæ; proportio aũt corporum ſphęricorum proportionem diametrorum ſuarum triplare perhibetur, vnde et Cometa ratiõe certa ad terrãcõparabitur, cumq; terræ molem tanq; notã ſubijciamus, corpulentia quoq; Cometę manifeſtabitur.

PROBLEMA Decimumquintum. Cauda Cometæ quantam habeat longitudinem docte ſciſcitari.

Priuſq; id aggrediemur intellexiſſe oportet caudã Cometæ nõ differre ſubſtantialiter a corpore Cometæ, verum tamen rariorem atq; leuiorem exiſtere, ꝓpter raritatem em̃ remiſſius lucere, ꝓpter leuitatem aũt ſurſum tendere perhibetur. Quo demum euenire eſtimandũ eſt rectam a centro mundi ad centrum Cometæ applicatam, ſi vltra porrigeretur per medium caudæ euadere, perinde ac ſi fuerit axis coni fumei, quem appellant caudam Cometæ. Præterea inſtrumenti officio, angulus quẽ ſubtendit ipſa cauda in viſu obſeruandus eſt. Quo autem ingenio id fiat, haud cuiq; difficile videri debet, cũ & ſuperius huiuſcemodi inſtrumento vſi ſumus. Nunc propoſiti abſoluendi gratia pingo circulum magnum a, b, c, d, cuius reſpectu circulus terrę h, l, inſenſibilem habet quantitatem, Centrum mundi ſit e, duo pũcta a, & d, terminent diametrum a, d, quorum alterũ videlicet a, vertici capitum ſupra ponatur, Alterum autem locũ teneat oppoſitum. Centrum viſus ſit h, a quo & centro mundi e, per centrũ Cometæ g, euadant duæ rectę, quarum altera quidem e, b, ad locum verum Cometæ, punctũ b, deſinat, Altera vero h, c, locum Cometæ viſum, punctum c, offendat, cui æquediſtans e, k, producatur, Arcus igitur b, k, inſenſibiliter ab arcu b, c, diuerſitate ſcilicet aſpectus Cometæ differens ex ſuperioribus innoteſcet, vnde & angulus b, e, k, atq; idcireo ſibi al-

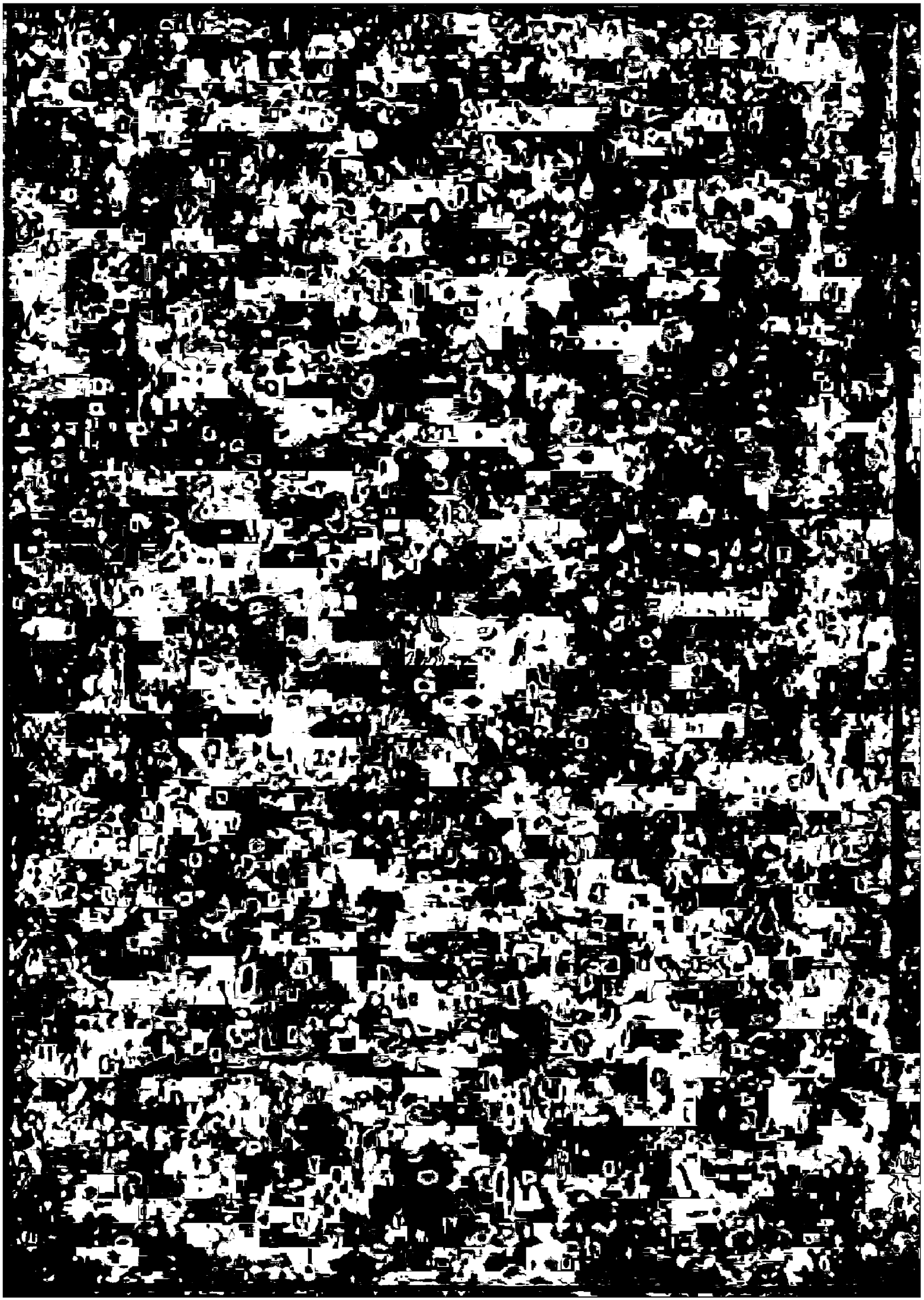


ternus e.g.h. haudquaq; latebunt. Sit demũ longitudo caudæ g.n. subtendens angulum visualem g.h.n. instrumenti auxilio mensuratum, adiunctaq; recta h.n. triangulus g.h.n. duos angulos apud g. & h. cognitos habebit, g. quidem propter cõsequentem e.g.h. notum, h. aũt per instrumentũ. Latus insuper h.g. ex supra memoratis cognitũ, quãobrem latus suum g.n. scilicet longitudo caudæ non ignorabitur. Quod si deinceps rectã g.n. ad terræ semidiametrum libet cõferre, linea h.g. sumpta mediatrice cuius respectu rectam g.n. iam nunc mensi sumus: ipsa autẽ per relationem ad e.h. paulo superius cognoscebatur, erit & ipsa g.n. eodem respectu mensurata, quod erat lucubrandum.

PROBLEMA Decimumsextum.
Grossiciem huiusmodi caudæ deinceps indagare

Caudam huiusmodi teretem existere conuenit. Aut igitur Kylindricę erit figurę aut conicę. Si Kylindricę, diametrũ cometæ superius cognitã in seipsam ducemus, indeq; productum in longitudinem caudæ. Columnæ eñ quadrilateræ hoc pacto creatæ ad caudã Cometæ proportio erit, sicut quadrati circulum ambientis ad ipsum circulum, quę ferme est vt quatuordecim ad vndecim. Grossities igitur Kylindri huiusmodi innotescet, cum columnam quadrilateram notã reddiderimus. Si vero fuerit conica basim quidem habens in corpore Cometæ: verticem aũt sublimem, inuenta grossitie Kylindri, vt pertactum est, tertiam eius partem pro grossitie caudæ computabimus. Kylindrus eñ coni eandẽ secum basim habentis, triplus demonstratur.

FINIS.



Appendix D.
"DE COMETA", ATTRIBUTED TO REGIOMONTANUS

Latin text taken from *Dialexis de novae et prius incognitae stellae inusitatae magnitudinis & splendidissimi luminis apparitione, & de eiusdem stellae vero loco constituendo.* per Thaddaeum Hagecium ab Hayck [Hajek]. Francofurti ad Moenum MDLXXIIII. (1967 facsimile, Prague) Reproduced with the permission of Yale University's Beineke Rare Book and Manuscript Library. This treatise is found on pages 146–149.

IOANNES DE MONTE REGIO

de Cometa

Idibus Ianuariis, anno Domini 1475 [sic] visus est Cometa sub Libra, cum stellis Virginis: cuius caput tardi motus erat, donec vicinaret spicae, nunc velocitabat suus incessus per crura Bootis, versus eius sinistram, a qua discedendo die uno naturali, portionem circuli magni 40 graduum descripsit. Ubi cum esset in medio Cancri, maxime distabat ab orbe signorum 77 gradibus, & tunc inter duos polos zodiaci & aequinoctialis, ibat usque ad interpedes Cephei. Deinde per pectus Cassiopeae, super Andromede ventrem, post gradiendo per longitudinem piscis septentrionalis, ubi iterum valde remittebatur motus eius, appropinquabat zodiaco, transiens ipsum iuxta medium Arietes: donec cum stellis Ceti occasus Eliacus nobis ipsum occultaret, in ultimis diebus Februarij. Hoc motu suo proprio circuli magni portionem descripsit. quo in septentrionem, & cum hoc contra successionem signorum ferebatur a Libra in Arietem in fine & principio proportionabiliter tarde: in medio vero eius apparitionis velocissime mouebatur, uno die fere per quatuor signa, a fine Virginis, usque ad principium Geminorum: & secundum naturam sibi adscribendam, motum continuasse debebat, donec iterum reversus in Libram apparuisset: & forsan taliter motus fuit, quoniam in eius occasu magne adhuc erat quantitatis. Tamen propter figuram eius ad Solem, & maxime in plagis septentrionalibus, non nisi parum in fini suae apparitionis videri poterat versus meridiem in diebus Aprilis, si motu suo regularitatem seruasset.

De motu caudae

Cauda vero eius minus mobilis, continue respiciendo stellas Geminorum, eas circuibat, nunquam ab eis per totum apparitionis tempus deviabat. Ideoque in prima eius apparitione caudam ad occidentem protendebat, quoniam illae stellae Geminorum putabantur. In fine vero cometae sub Ariete locato propter Solis vicinitatem, nisi in occidente apparuit, protendens caudam versus orientem: quia in hoc situ stellae Geminorum ponebantur. In medio vero apparitionis cum iret inter duos polos, caudam vertebat ad meridiem: illic tunc erant stellae Geminorum: contingebatque tunc nocte eadem: ut statim post Solis occasum cauda Orientem respiceret. Appropinquante medio noctis, respexit meridiem. Post medium noctis, respexit occidentem. Ante Solis ortum, indicabat locum septentrionis: unde circulus stare consueuit. Haec caude diversitas in situ ex motu diurno oriebatur, quem cometa habuit: ex motu continentis insequentis primum mobile, qui semper est ab oriente in occidentem, motu autem proprio extremitas caudae (quamvis tardius quam caput cometae) semper tamen etiam ad occidentem,

contra signorum successionem, describens parallelum a principio Librae usque ad medium Tauri movebatur: vadens sub pedibus Vlulantis: per Vrsam maiorem appropinquando Perseo: per quem circa Pleiades, ad caudam Arietis, ibat fere in medio Tauri. Vnde patet, tam caput quam cauda cometae versus occidentem, & nunquam versus orientem iuisse, non solum motu diurno, set etiam proprio.

De distantia Cometae a terra

Qui Geometriae & Arithmeticae rationes nouerunt, minime dissentient eis quae ex Ptolemaei traditionibus habentur: quibus in Almagesto demonstrauit, concauum orbis lunae 33 vicibus tantum distare a centro terre, quantum est ab eodem centro ad terrae superficiem. Semidiameter vero terrae (ut colligi potest) continet fere 913, miliaria Teutonica: & per ipsum (ut dicit Alphraganus 23 differentia) ratiocinamur distantias stellarum a terra. Considerando itaque maximam diuersitatem aspectus capitis cometae a Spica stella sibi vicina, quae iuxta possibilitatem omnibus difformitatibus reductis, maior comprehendi non poterat quam 6 graduum, instrumentis congruis ad hoc ordinatis: ad quam aspectus diuersitatem necessario sequitur, corpus Cometae a superficie terrae distitisse in nonecupla distantia ad semidiametrum terrae: quae ad minus est octo millia & ducenta milliaria: ponebaturque in superiori parte supremae regionis aeris, & non in igne: supposita decupla quantitate commensurationis elementorum: sicut philosophus secundo de generatione determinauit.

Quomodo inueniatur magnitudo cometarum

Quantitas vero cometarum comprehenditur ex distantia illorum a terra, & quantitae anguli sui pyramidis visualis. Nam uni gradui in circulo magno correspondent 16 miliaria de circumferentia terrae. Cum ergo distiterit cometa a superficie terrae tantum quantum est semidiameter terrae, & chordauerit eius corpus unum gradum, erit diameter corporis ipsius 16 miliaria. Si vero in duplo distiterit, dupla erit quantitas eius: qualis est enim proportio totius sinus (scilicet 60 ad distantiam stellae a terra) talis es proportion chordae ad perimetrum stelle. Chordam dico, que subtenditur portioni circuli magni in coelo, quam talis stella chordat, & talis chorda est basis pyramidis visualis istius stellae. Multiplicetur ergo basis pyramidis visualis per distantiam comete a terra, & productum diuidatur per 60. Ipse quotiens est quantitas diametri cometae: cuius demonstratio alteri loco competit. Distantia vero cometae a terra comprehenditur ex diuersitate aspectus ipsius cometae, vel alicuius eius partis, ad aliquod Astrum sibi vicinum.

De magnitudine cometae

Cum enim diameter capitis cometae undecim minuta circuli magni chordaret: ut instrumentis deprehendebatur: quorum minutorum chorda est undecim minuta, & medium fere: illa ergo chorda, ut dictum est in prima parte, multiplicetur in distantiam cometae a terra; id est octo millia & 200 milliaria: & producentur 94 millia, & 300: quae diuidantur per sinum totum, scilicet 3 millia & 600 minuta, exibunt inde 16 [sic] miliaria: quae est quantitas diametri capitis cometae: comae vero circunquaque egredientes de capite cometae chordabunt fere 34 minuta. Fit ergo diameter earum 81 miliaria fere ** Eusebius Ecclesiasticae historiae, li. 3. Et cometes praeterea exitialibus flammis ardere per totum visus est annum. Ex Iosepho: nulla impressio aerea potest ex naturalibus causis exhalationum flammiuorarum sufficere materiam cometae spacio anni, sed veniunt cometae ex occultis causis naturae, &c. In qua sententia est Messala Arabs.

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TEORIA KOMET W EUROPIE XV WIEKU

Polish Summary

Książka Jane L. Jervis o sposobach interpretacji zjawiska komet w XV wieku ważna jest dla dziejów nauk przyrodniczych, zwłaszcza astronomii, z wielu powodów. Zainteresowanie kometami pobudzało astronomów do podejmowania bezpośrednich obserwacji nieba, wpływało na poszukiwanie nowych form wyrażenia w sposób matematyczny torów komet, wreszcie sprzyjało zakwestionowaniu arystotelesowskiej struktury kosmosu. Ponadto aspekt „dziwności" zjawiska komety działał silnie na wyobraźnię i pobudzał zainteresowania astrologiczne.

Jane L. Jervis przedstawia teorie komet w XV wieku uwzględniając trzy pierwsze z wymienionych aspektów i stara się ukazać naukowe osiągnięcia tego stulecia. Omawia dzieła Jakuba Angelusa, Pawła Toscanellego, Jerzego Peurbacha i Jana Regiomontana. Nie odczytane wcześniej rękopisy Toscanellego wypełniają lukę w dziejach nauki okresu renesansu i każą widzieć tę naukę w nieco innym niż dotychczas świetle.

Problematyka komet ukazana jest w książce w szerokim kontekście czasowym: punktem wyjścia rozważań jest zwięzłe omówienie teorii komet począwszy od starożytności (Arystoteles, Seneka, Pliniusz Starszy, Ptolemeusz) i średniowiecza (Albert Wielki, Piotr z Limoges, Godfryd z Meaux), co uzasadnione jest faktem czerpania pomysłów z tych teorii jeszcze w XV wieku. Natomiast w Epilogu Autorka przedstawia zagadnienia komet w XVI i u początków XVII w., sygnalizując działalność Hieronima Frascatora, Piotra Apiana, Hieronima Cardana, Jana Vögelina, Kopernika, Tychona Brahe, Hajeka, wreszcie Maestlina i Keplera. Dzięki temu książka jest nie tylko monografią pojęć i koncepcji na temat komet wyznawanych w XV w., ale ma także wartość encyklopedii w zakresie teorii kometarnych począwszy od Arystotelesa i Seneki, a skończywszy u progu czasów nowożytnych.

Przedmiotem szczegółowych analiz jest seria najważniejszych i najbardziej dla XV wieku reprezentatywnych traktatów o kometach, przedstawiających szczególną wartość dla rozwoju astronomii, pominięto natomiast traktaty, w których komety są przedmiotem wyłącznie zainteresowań astrologicznych. Badania skupione są na technikach obserwacji komet i rodzajach stosowanych instrumentów, a także na jakości obserwacji oraz sposobie dokonania zapisu wyników. Następnym etapem jest wykazanie, czy i w jakim stopniu dane obserwacji stanowiły materiał do opracowania teorii komet w XV wieku, to znaczy wyjaśnienia natury komet i określenia sposobu ich lokalizacji.

Autorka rozpoczyna analizą dziełka Jakuba Angelusa *Tractatus de cometis* (o komecie z roku 1402). Angelus cytuje opinię Seneki na temat natury komet sugerującą, że komety mogą być szczególnym rodzajem planet widocznych z Ziemi tylko wówczas, gdy znajdują się w dolnych partiach swych orbit. Opinia ta, przeciwna zdaniu Arystotelesa traktującego komety jako zjawisko atmosferyczne (zgęszczone opary Ziemi ulegające zapaleniu), była uprzednio pomijana w rozważaniach o kometach. Poza tym jednak dziełko Angelusa, podające tylko jakościowy opis komety, stanowi przedłużenie tradycji średniowiecznej.

Najważniejszą postacią w dziejach interpretacji komet w XV wieku jest Paweł Toscanelli, matematyk i uczony pozostający dotychczas na marginesie zainteresowań historyków astronomii. Autorka szczegółowo analizuje dane dotyczące systematycznych obserwacji sześciu komet,

które pojawiły się w okresie między rokiem 1433 a 1472, przechowane w rękopisach Toscanellego. W przeciwieństwie do Angelusa Toscanelli, prawdopodobnie po raz pierwszy w astronomicznej tradycji Europy, próbuje metodami obliczeniowymi zrekonstruować krzywą zakreślaną przez kometę. Posługuje się przy tym serią map nieba, gdzie dzienna droga komety wyznaczona jest na tle pozycji planet i gwiazd stałych. Analiza tych materiałów ukazuje rozwój techniki obserwacyjnej i obliczeniowej stosowanej przez Toscanellego. Osiągnięcia Toscanellego, prawdopodobnie znane Regiomontanowi, mogły wywrzeć wpływ na dalszy rozwój teorii komet w XV w., chociaż na podstawie dotychczasowych badań trudno ustalić, czy było tak w rzeczywistości.

Prace nad kometami prowadzone przez Regiomontana i jego mistrza Peurbacha wypełniają osobne rozdziały. Peurbach zainteresował się kometą z 1456 r. (znaną później jako kometa Halleya) i prawdopodobnie pierwszy starał się określić największe zbliżenie komety do Ziemi. Przybliżona wartość paralaksy komety skłoniła go do ustalenia dolnej granicy odległości komety od Ziemi na „przynajmniej 1000 mil niemieckich". Natomiast górną granicą, przyjętą jako pewnik, pozostała sfera Księżyca, Peurbach był bowiem wyznawcą Arystotelesowskiej teorii komet jako zjawisk sfery podksiężycowej.

Dzieło Regiomontana, znane jako *Szesnaście problemów* (1472), przedstawia wypracowane przez tego matematyka i astronoma techniki geometryczne, mające służyć do określania torów komet na podstawie ich dziennej paralaksy. Techniki owe, gdyby były poparte odpowiednio dokładnymi obliczeniami, pozwoliłyby rozwiązać na drodze matematycznej odwieczny problem kosmologiczny natury komet.

Zdaniem Autorki największym osiągnięciem astronomii XV w. jest potraktowanie komet, wbrew Arystotelesowi, jako ciał niebieskich. Było to konsekwencją zastosowania do ich badań metod astronomicznych.

Grażyna Rosińska

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